Benthic TMDL for Toms Brook in Shenandoah County, Virginia

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CHAPTER 1: EXECUTIVE SUMMARY

1.1. Background

Toms Brook, located in Shenandoah County, Virginia, is a tributary of the North Fork Shenandoah River (VAV-B50R, HUC 02070006). The headwaters of Toms Brook originate southwest of the town of Mount Olive. Jordan Run, a tributary of Toms Brook, originates north-east of Saumsville. The confluence of these two streams is approximately 0.67 miles (1.1 km) upstream of the confluence of Toms Brook with the North Fork Shenandoah River. The Toms Brook watershed is 4,252 hectares (10,506 acres), oriented along a northwest-southeast axis.

Biological monitoring of Toms Brook over a period of 5 years indicated that the waterbody did not support the “general standard” of water quality in Virginia. Along with a number of standards for specific pollutants, Virginia also has a general standard, which states that a waterbody must be free of pollutants or environmental stresses that substantially alter the aquatic biological community. Impairment is defined by two or more ratings (over the assessment period) of “moderate” or “severe” based on the Environmental Protection Agency’s (EPA’s) Rapid Bioassessment Protocol (RBP) II. Biomonitoring has been conducted on Toms Brook since 1995. Originally listed in 1998 with a benthic impairment, Toms Brook was also included on the 2002 303(d) TMDL priority list in Virginia. During the most recent assessment period (2002), Toms Brook’s benthic community was monitored 6 times, with 5 of those assessments receiving a “moderately impaired” rating. The overall rating for each of these assessment periods has consistently been “moderately impaired”, leading to Toms Brook’s placement on Virginia’s 303(d) list of impaired water bodies with a benthic impairment. As such, it does not fully support the Clean Water Act’s Aquatic Life Use. The impairment extends from the headwaters of the Toms Brook branch downstream to its confluence with the North Fork Shenandoah River, for a total of 7.18 stream miles.

Physical and chemical monitoring of Toms Brook during the 2002 assessment period occurred at an ambient water quality monitoring station co-located with the biological monitoring station. Data collected from biomonitoring is used to determine the health of the benthic community, but does not identify the source(s) of stress on the community. In order to identify the stressor that may be causing the benthic impairment, the EPA has developed a stressor identification process to identify key stressors. Organic matter, nutrients, ammonia and sediment were all determined to be possible stressors, with sediment selected as the most probable stressor of the benthic community in this watershed. The TMDL was then developed for sediment. Sediment sources were identified, a TMDL load calculated, a margin of safety applied, and load allocation scenarios were created.

In order to remedy the water quality impairment pertaining to the biological community, the Total Maximum Daily Load (TMDL) was developed to take into account all potential stressors and a margin of safety (MOS). A glossary of terms used in the development of this TMDL is listed in Appendix A.

1.2. Sources of Sediment

Sediment is delivered to the impaired segments of Toms Brook through the processes of surface runoff, channel and streambank erosion, and from point source inputs, as well as from background geologic processes. Natural sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, and residential land uses. During runoff events, sediment loading occurs from both pervious and impervious surfaces in the watershed. Streambank erosion is caused by reduction in riparian cover resulting in stream bank instability and increased runoff rates related to anthropogenic sources in the watershed. Animals grazing on pastures in riparian areas with access to streams also contribute to streambank erosion. Transport of sediment is further increased by increasing areas of imperviousness in a watershed from residential growth and development, which increase the flow volume and peak rates of surface runoff.

1.3. Modeling

Because Virginia has no numeric in-stream criteria for sediment, a “reference watershed” approach was used to define allowable TMDL loading rates in the impaired watershed. The reference watershed approach pairs two watersheds – one whose streams are supportive of their designated uses and one whose streams are impaired.

The Hays Creek watershed was selected as the TMDL reference watershed for Toms Brook. The TMDL sediment target load was defined as the modeled sediment load for existing conditions from the non-impaired Hays Creek watershed, area-adjusted to Toms Brook.

The Generalized Watershed Loading Function (GWLF) model (Haith et al., 1992) was selected for comparative modeling for both the impaired and TMDL reference watersheds in this TMDL study. Observed flow data were not available to calibrate the GWLF model, so the model was used with recommended model parameters for the land uses and conditions found in the Toms Brook and Hays Creek watersheds.

1.4. Benthic TMDL for Sediment

The benthic TMDL for the Toms Brook watershed was developed using sediment as the pollutant and the Hays Creek watershed as the TMDL reference watershed. The Toms Brook watershed is one-fifth (0.2043) the area of the Hays Creek watershed. In order to establish a common basis for comparing loads between these two watersheds, each land use category in Hays Creek watershed was decreased by multiplying by this factor. This resulted in an area-adjusted Hays Creek watershed equal in size with the land area in the impaired Toms Brooks watershed (4,866 ha). The average annual sediment load in metric tons per year (t/yr) from the area-adjusted Hays Creek was used to define the TMDL sediment load for Toms Brook, as shown in Table 1.1. Loads were based on average annual sediment loads using the 10-yr period, January 1985 – December 1994, as representative of both wet and dry periods of precipitation.

Table 1.1. Toms Brook TMDL - Existing Sediment Loads (t/yr)

	Toms Brook		Area-adjusted Hays Creek	
Surface Runoff Sources	**(t/yr)**	**(t/ha)**	**(t/yr)**	**(t/ha)**
High Till	1,974.2	32.7	325.1	26.4
Low Till	466.3	1.8	1,015.0	19.1
Pasture	2,007.8	0.2	3,325.1	0.3
Forest	316.9	0.0	196.9	0.0
Pervious Urban	35.4	2.0	0.9	0.3
Impervious Urban	40.8	3.4	1.0	0.4
Other Sources				
Channel Erosion	259.5		2.0	
Point Sources	2.4		0.0	
Watershed Totals	**5,103.4**		**4,866.0**	
		Target Sediment TMDL Load =	**4,866.0**	**t/yr**
		10% MOS =	486.6	t/yr
		Load for Allocation =	**4,379.4**	**t/yr**

The benthic TMDL for Toms Brook is comprised of the three required TMDL load components – the waste load allocation (WLA) from point sources, the load allocation (LA) from nonpoint sources, and a margin of safety (MOS), each of which is quantified in Table 1.2. An explicit 10% margin of safety (MOS) was included in the calculation. The waste load allocation (WLA) included permitted TSS loads from all permitted sources.

Table 1.2. Toms Brook TMDL Sediment Goal

TMDL (t/yr)	WLA (t/yr)	LA (t/yr)	MOS (t/yr)
4,866.0	8.1	4,371.3	486.6
	VA0061549 = 7.83 VAG110076 = 0.04 SFH General Permits = 0.25		

1.5. TMDL Reductions and Allocations

TMDL allocation scenarios were developed by consolidating nonpoint source loads into 3 categories – agriculture, urban, and forestry – and then comparing category loads from the Toms Brook watershed to those of its area-adjusted reference watershed – Hays Creek. These categorized loads and the reductions from several alternative scenarios required to meet the TMDL are shown in Table 1.3. Because future land use change in the watershed was considered to be minimal, TMDL modeling for the allocation runs was performed using the existing land use scenario for Toms Brook.

Table 1.3. TMDL Allocation Scenarios for Toms Brook

	Reference	Existing	Toms Brook TMDL Sediment Load Allocations					
Source	Hays Creek	Toms Brook	**TMDL Alternative 1**		**TMDL Alternative 2**		**TMDL Alternative 3**	
Category	(t/yr)	(t/yr)	(% reduction)	(t/yr)	(% reduction)	(t/yr)	(% reduction)	(t/yr)
Agriculture	4,665.2	4,448.4	**14.3%**	3,812.1	**14.5%**	3,802.4	**15.1%**	3,776.4
Urban	1.9	76.2	**14.3%**	65.3	0%	76.2	0%	76.2
Forestry	196.9	316.9	**14.3%**	271.6	**14.5%**	270.9	**10.0%**	285.2
Channel Erosion	2.0	259.5	**14.3%**	222.4	**14.5%**	221.8	**10.0%**	233.5
Point Sources	0.0	2.4	0%	8.1	0%	8.1	0%	8.1
Total	**4,866.0**	**5,103.4**		**4,379.4**		**4,379.4**		**4,379.4**

In each of the allocation scenarios, point sources were increased from the existing loads in order to represent their VPDES permit limits. TMDL Alternative 1 is achieved by taking equal percent reductions from all other sources. Since the urban load is less than 2% of the total sediment load, TMDL Alternative 2 is achieved without reduction to the urban load and requires equal percent reductions from the remaining 3 source categories. TMDL Alternative 3 is achieved by taking a larger percent reduction from the largest source category – Agriculture – and a smaller, equal percent reduction from the remaining two source categories. Concerns were expressed both at the final public meeting and in follow-up comments that equal % reductions should be required from all categories. Alternative 1 best addresses these concerns and is, therefore, recommended as the TMDL allocation scenario to use as a starting point for implementation planning.

The TMDL to address the benthic impairment in Toms Brook is 4,866.0 t/yr of sediment, includes a 10% margin of safety, and will require an overall reduction equal to 14.3% of the existing sediment load.

1.6. Reasonable Assurance

Continued biological and chemical monitoring in the watershed by VADEQ, provisions of Virginia's WQMIRA (Water Quality Monitoring, Information, and Restoration Act of 1997) legislation requiring implementation of developed TMDLs, and the potential of funding through Section 319 and USDA's CREP (Conservation Reserve Enhancement Program) programs all provide the basis for a reasonable assurance that this TMDL will be implemented.

1.7. Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progress made. In May 2002, an initial trip was made to the watershed to meet with regional DEQ and local NRCS field personnel, to take a windshield tour of the watershed led by Jim Lawrence with The Opequon Watershed group, and to meet the coordinator of the Friends of the Shenandoah River volunteer monitoring group. On March 27, 2003, the first public meeting on the Toms Brook TMDL was held at the Toms Brook Fire Station in Toms Brook, Virginia, with approximately 24 people in attendance. The purpose of this meeting was threefold: to inform local citizens and stakeholders of the impairment, to explain the work that had been completed up to that point in identifying the benthic stressors, and to encourage the sharing of information about the watershed. Personnel from the Department of Environmental Quality (DEQ), the Department of Conservation and Recreation (DCR), and the Virginia Tech TMDL group presented information and data. Questions from the audience followed the presentations. The second and final public meeting will be held on January 13, 2004, at the Toms Brook Fire Station in Toms Brook. Approximately 30 people attended the final meeting. Copies of the presentation materials were available for public distribution at the meeting. The draft TMDL report was made available to the public for comment at the final public meeting and on the DEQ website. Four sets of comments were received, and DEQ responded to each of those comments in the final draft.

CHAPTER 2: INTRODUCTION

2.1. Background

2.1.1. TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (USEPA, 1998; 40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant sources, and provides a framework for taking actions to restore water quality.

2.1.2. Impairment Listing

Toms Brook has been listed as impaired on Virginia's 1998 and 2002 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ; 1998, 2002a) due to water quality violations of the General Standard (listed as a benthic impairment). The Virginia Department of Environmental Quality has delineated the impairment on Toms Brook. The impaired reach is 7.18 miles (11.56 km) in length, beginning at the headwaters of Toms Brook and ending at the confluence with the North Fork Shenandoah River, approximately 0.54 miles (0.87 km) miles downstream from the biological monitoring station. The Toms Brook benthic TMDL is targeted for completion in January 2004.

2.1.3. Watershed Location and Description

Toms Brook, located in Shenandoah County, is a tributary of the North Fork Shenandoah River (VAV-B50R, HUC 02070006). The headwaters of Toms Brook originate southwest of the town of Mount Olive. Jordan Run, a tributary of

Toms Brook, originates north-east of Saumsville. The confluence of these two streams is approximately 0.67 miles (1.1 km) upstream of the confluence of Toms Brook with the North Fork Shenandoah River. The impaired section of Toms Brook includes the entire stream from its headwaters to its confluence with North Fork Shenandoah River. The Toms Brook watershed (Figure 2.1) is 4,252 hectares (10,506 acres), oriented along a Northwest-Southeast axis. Based on the NLCD land use dataset, approximately 6% of the land use in the watershed is urban and residential, 49% is pasture, 43% is forested, and 2% is cropland.

Toms Brook enters the North Fork Shenandoah River 7.18 miles from its headwaters; the North Fork Shenandoah flows northeast to join the South Fork Shenandoah River to become the Shenandoah River. The Shenandoah is a tributary of the Potomac River, which discharges into the Chesapeake Bay.

2.1.4. Pollutants of Concern

Pollution from both point and nonpoint sources can lead to a violation of the general standard for water quality. A violation of this standard is assessed on the basis of measurements of the benthic macroinvertebrate community in the stream, with pollution impacts referred to as a benthic impairment. Water bodies having a benthic impairment are not fully supportive of the aquatic life designated use for Virginia's waters.

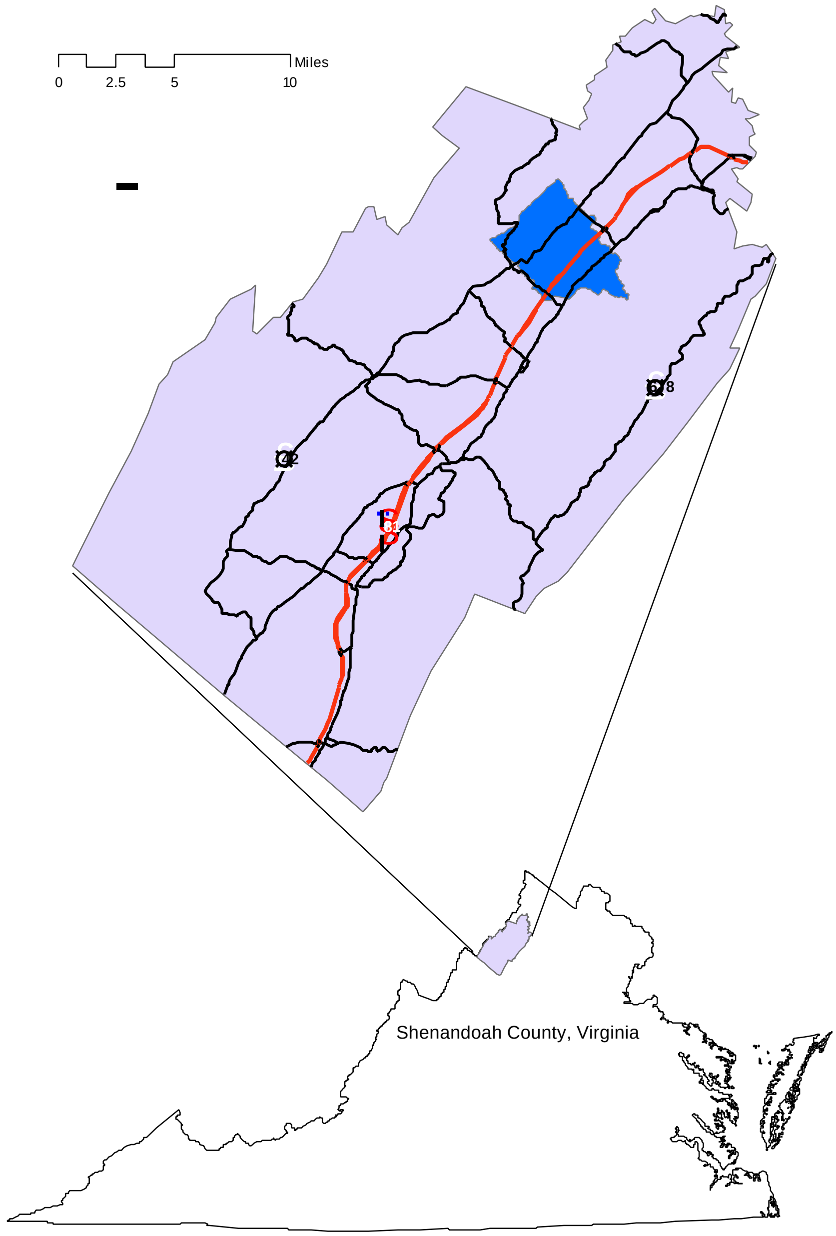


Figure 2.1. Location of Toms Brook Watershed

2.2. Designated Uses and Applicable Water Quality Standards

2.2.1. Designation of Uses (9 VAC 25-260-10)

"A. All state waters are designated for the following uses: recreational uses (e.g. swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)" SWCB, 2003.

Toms Brook does not fully support the aquatic life designated use due to violations of the general (benthic) criteria listed below.

2.2.2. General Standard (9 VAC 25-260-20)

The general standard for a water body in Virginia is stated as follows:

"A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.

Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled." SWCB, 2003.

The biological monitoring program in Virginia that is used to evaluate compliance with the above standard is run by the Virginia Department of Environmental Quality (DEQ). Evaluations of monitoring data from this program focus on the benthic (bottom-dwelling) macro (large enough to see) invertebrates (insects, mollusks, crustaceans, and annelid worms) and are used to determine whether or not a stream segment has a benthic impairment. Changes in water quality generally result in alterations to the quantity and diversity of the benthic organisms that live in streams and other water bodies. Besides being the major intermediate constituent of the aquatic food chain, benthic macroinvertebrates are "living recorders" of past and present water quality conditions. This is due to their relative immobility and their variable resistance to the diverse contaminants that are introduced into streams. The community structure of these organisms provides the basis for the biological analysis of water quality. Qualitative and semi-quantitative biological monitoring has been conducted by DEQ since the early 1970's. The US EPA Rapid Bioassessment Protocol (RBP) II was employed beginning in the fall of 1990 to utilize standardized and repeatable methodology. For any single sample, the RBP produces water quality ratings of “non-impaired,” “slightly impaired,” “moderately impaired,” and “severely impaired.” In Virginia, benthic samples are typically taken and analyzed twice a year in the spring and in the fall.

The RBP II procedure evaluates the benthic macroinvertebrate community by comparing ambient monitoring “network” stations to “reference” sites. A reference site is one that has been determined to be representative of a natural, unimpaired water body. The RBP II evaluation also accounts for the natural variation noted in streams in different ecoregions. One additional product of the RBP evaluation is a habitat assessment. This is a stand-alone assessment that describes bank condition and other stream and riparian corridor characteristics and serves as a measure of habitat suitability for the benthic community.

Determination of the degree of support for the aquatic life designated use is based on biological monitoring data and the best professional judgment of the regional biologist, relying mostly on the most recent data collected during the current 5-year assessment period. In Virginia, any stream segment with an overall rating of “moderately impaired” or “severely impaired” is placed on the state’s 303(d) list of impaired streams (VADEQ, 2002b).

CHAPTER 3: WATERSHED CHARACTERIZATION

3.1. Water Resources

The main branch of Toms Brook runs for 7.18 miles from the headwaters until it enters the North Fork of the Shenandoah River. Jordon Run is a major tributary to Toms Brook, and enters Toms Brook about 0.6 miles upstream from its confluence with the North Fork of the Shenandoah River.

3.2. Ecoregion

The Toms Brook watershed is located in the Central Appalachian Ridge and Valley Level III Ecoregion, and the Northern Limestone/Dolomite Valleys Level IV Ecoregion. Small areas of the Toms Brook watershed are in the Northern Sandstone Ridges and the Northern Shale Valleys Level IV Ecoregions. This Level III Ecoregion has numerous springs and caves. The ridges tend to be forested, while limestone valleys are composed of rich agricultural land (USEPA, 2002). The Northern Limestone/Dolomite Valleys Level IV Ecoregion has fertile land and is primarily agricultural. Steeper areas have scattered forests composed mainly of oak trees. Streams tend to flow year-round and have gentle slopes and distinctive fish communities. The ecoregion is composed primarily of Appalachian oak forest (Woods et al., 1999).

3.3. Soils and Geology

The main general soil map units found in Toms Brook watershed is the Frederick series. Frederic soils (generally silty loam) are deep and well drained. These soil types are typically found on ridgetops and sideslopes. Other soils found in significant portions in the Toms Brook watershed are the Berks series and the Weikert series (SCS, 1985).

3.4. Climate

The climate of the watershed is based on the meteorological observations made by the National Weather Service station in Woodstock, Virginia. This station is located approximately 2.5 miles (4.0 km) northeast of the town center of Woodstock. The station is located south of the watershed and 3.8 miles (6.2 km) from the centroid of the watershed. Average annual precipitation at the Woodstock station is 35.42 inches with 57.5% of the precipitation occurring during the crop-growing season (May-October). Average annual snowfall is 23.6 inches with the highest snowfall occurring during January. Average annual daily temperature is 54.6°F. The highest average daily temperature of 75.0°F occurs in July while the lowest average daily temperature of 33.9°F occurs in January (SERCC, 2002).

3.5. Land Use

Land use for Toms Brook watershed was derived from the National Land Cover Dataset (NLCD). This data is available from the United States Geological Survey (USGS) and is based on early-1990's data from the Landsat Thematic Mapper satellite data. Based on a conglomeration of the 21 land uses in the NLCD data, the main land use category in Toms Brook is pasture, comprising approximately 49% of the total watershed area. Forest, urban/residential, and cropland acreage accounts for about 43%, 6%, and 2% of the watershed area, respectively, as shown in Figure 3.1.

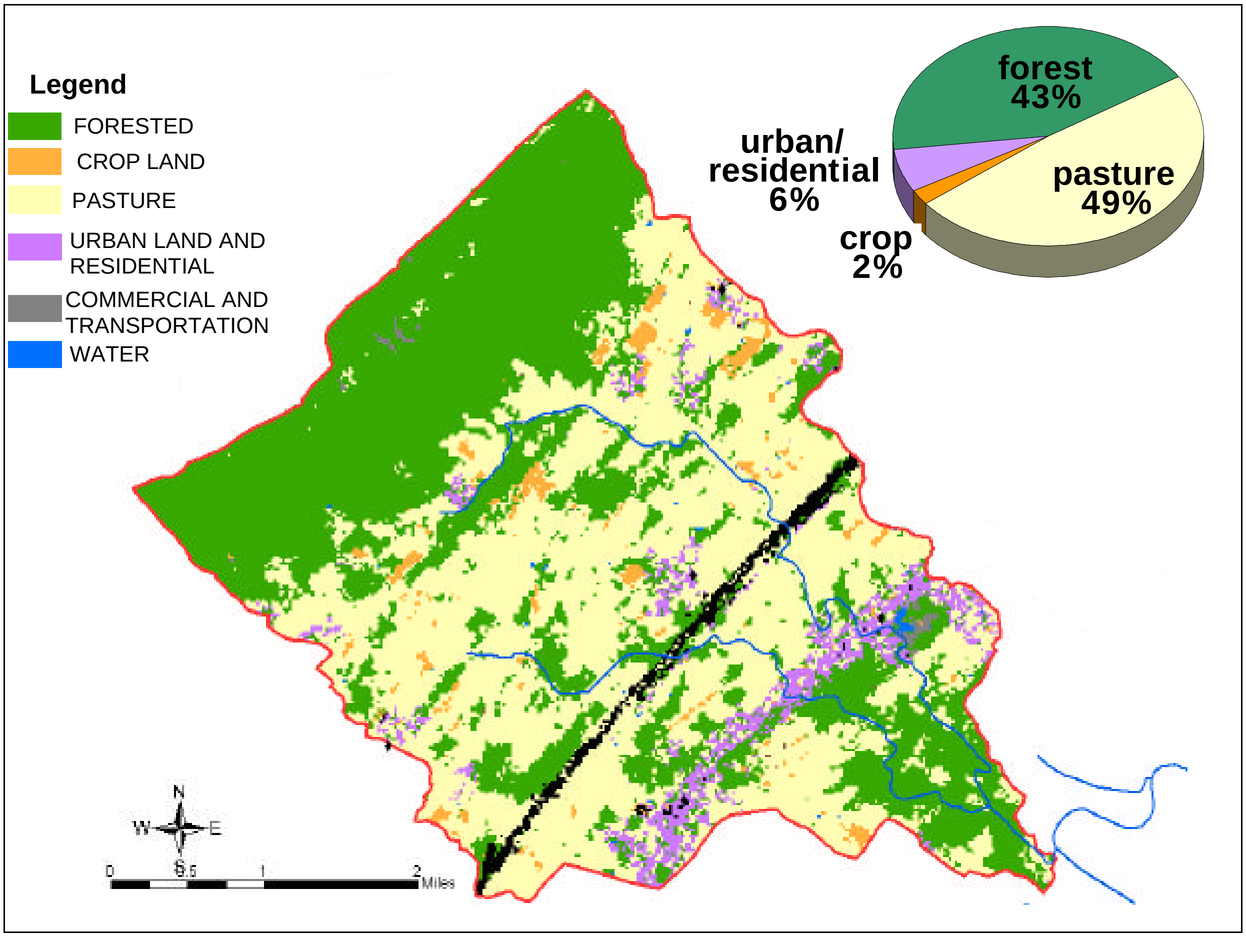


Figure 3.1. Land Use in Toms Brook Watershed

3.6. Future Land Use

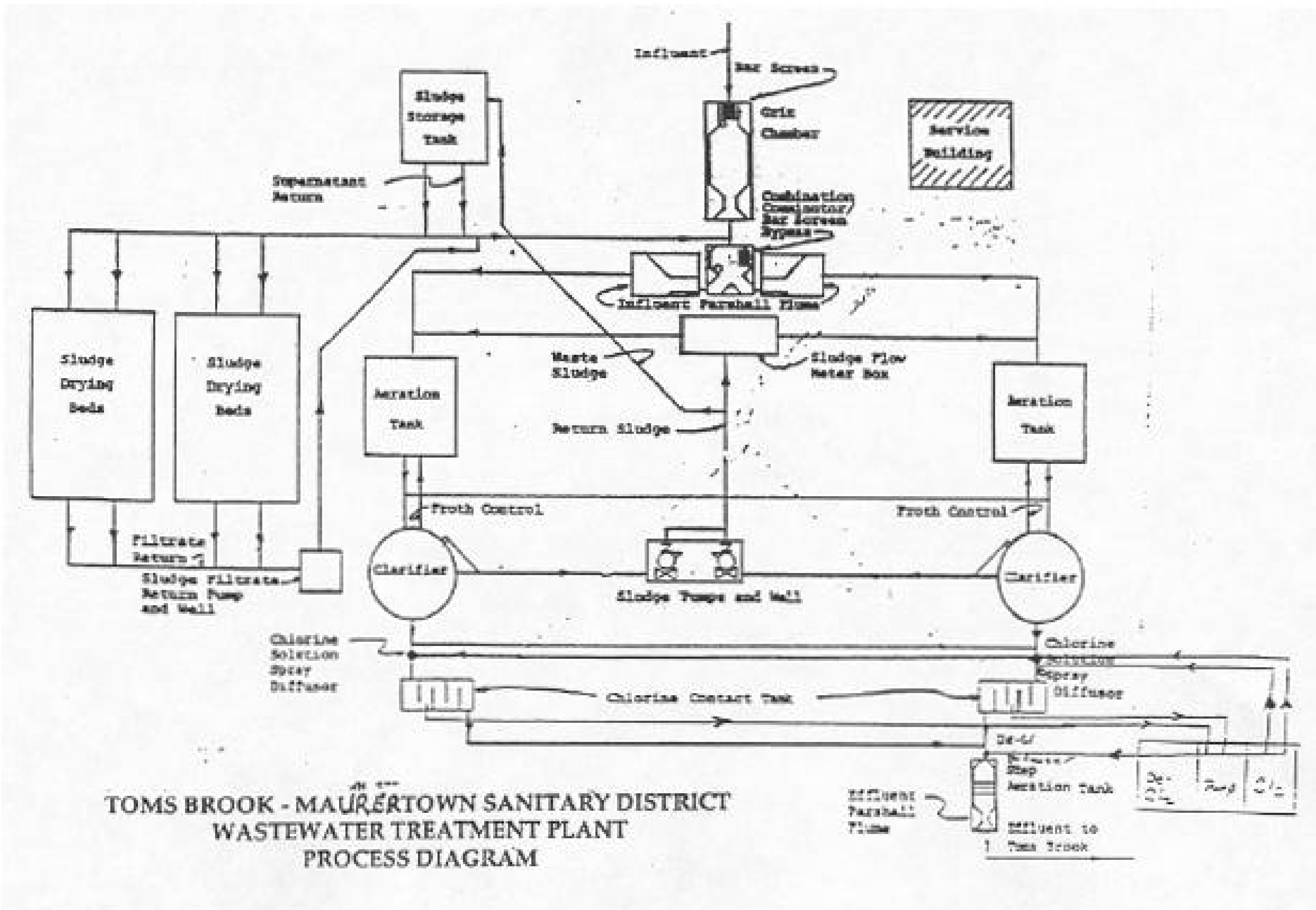
Discussions with the STP manager indicated no plans to expand in the near future, and with most of the current residential area within the Rt. 11 corridor where sewer lines are available, it appeared that there were limitations to septic tank installations in the area which would further confine future development along that corridor. So, based on these observations and conditions, land use in Toms Brook watershed was not expected to change significantly in the foreseeable future. Therefore, the TMDL loads and allocations were modeled based on existing conditions.

3.7. Toms Brook – Mauertown Sanitary District STP Description

The most significant permitted point source in the watershed is the Toms Brook – Mauertown Sanitary District STP (VA0061549). The plant consists of preliminary treatment (bar screen, grit removal, and flow measurement), dual aeration tanks (166,000 gallons each), dual settling tanks (28,000 gal each), dual chlorine contact tanks, dechlorination, post aeration, and flow measurement (Figure 3.2). A septage handling facility consists of two aerated receiving tanks (20,000 gallons each) and a macerator. Sludge treatment consists of a single aerobic digestor (20,000 gallons) and four drying beds. The District's preferred method for sludge disposal is land application of the aerobically digested sludge. The design capacity and permit limits for the plant are shown in Table 3.1. The discharge from the plant is generally small compared to the stream flow, however as is documented later, the plant has historically had operational problems in late December and early January, which have resulted in short-term exceedences of the STP's permitted effluent limits.

Table 3.1. VPDES Dischargers in Toms Brook Watershed

			Permitted Monthly Averages			
PERMIT	FACILITY	Design Flow (MGD)	BOD_5 (mg/L)	Sus. Solids (mg/L)	NH_4-N Jan-May (mg/L)	NH_4-N Jun-Dec (mg/L)
VA0061549	Toms Brook STP	0.189	30	30	5.4	4.6



TOMS BROOK - MAURERTOWN SANITARY DISTRICT
WASTEWATER TREATMENT PLANT
PROCESS DIAGRAM

Figure 3.2 Toms Brook - Mauertown Sanitary District STP

3.8. Water Quality Data

Virginia DEQ has monitored chemical water quality in the watershed since 1991. TMB000.54 is the historical DEQ station used for both ambient and benthic data collection and was used as the basis for the impairment listing in 1998. Ambient monitoring at station TMB000.54 was performed quarterly from 1991 through 1999, and bi-monthly from May 1999 through May 2001, when monitoring was discontinued. Ambient monitoring continued at the station once again on a monthly basis from April to June 2003, as part of a special study. Data has been monitored at several other sites within the Toms Brook watershed, as shown in Figure 3.3. As part of the current TMDL study, monthly samples were collected at sites TB1, TB2, and TB3 by The Opequon Watershed volunteers and analyzed at the BSE Water Quality Laboratory during the months of March and April 2003. DEQ also conducted a special study at three additional sites in the watershed (TMB000.70, TMB002.22, and JDN000.29) from April through June 2003 to assist in separating out influences from the Toms Brook STP and Jordon Run. Additionally, a local citizen's monitoring group, the Friends of the North Fork of the Shenandoah River (FOSR), had been monitoring two sites for a number of years: NS-13 upstream from Toms Brook STP, and NS-05, the STP effluent. FOSR also agreed to continue monitoring at the TB1, TB2, and TB3 sites until our TMDL study was complete.

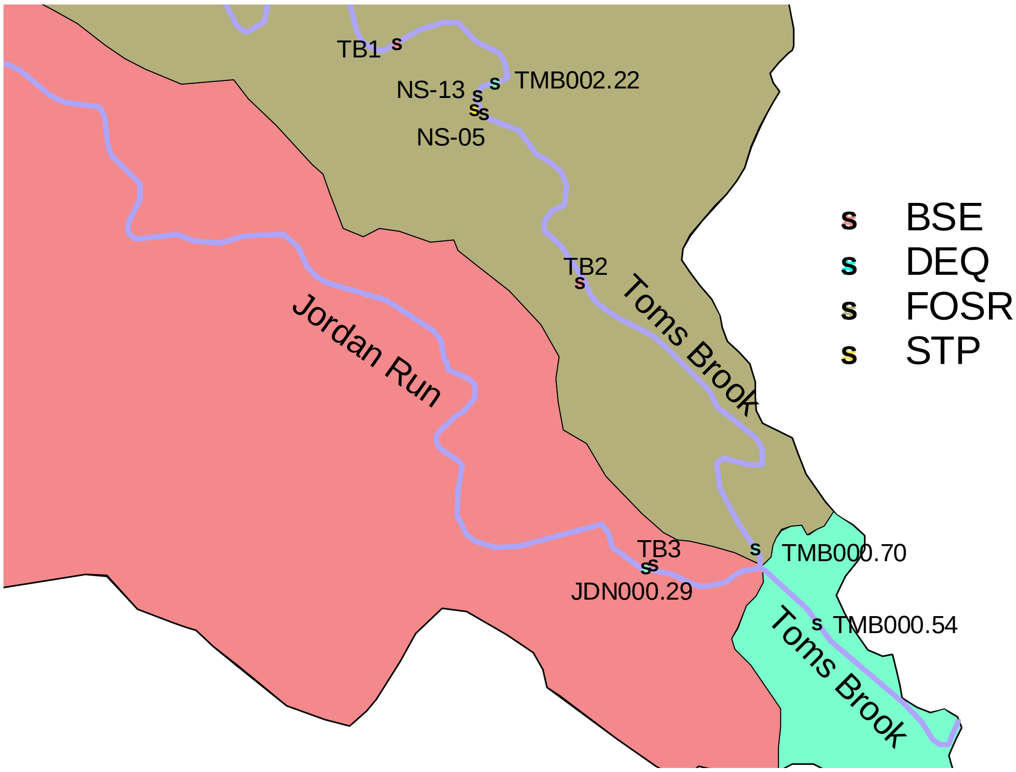


Figure 3.3. Monitoring Sites in the Toms Brook Watershed

3.9. Biological Monitoring Data

Biological communities have been monitored at TMB000.54 annually or semi-annually from October 1995 through the present. Toms Brook was originally placed on the 303(d) list in 1998 for a moderate benthic impairment. For the 2002 assessment, Toms Brook also received an overall rating of “moderately impaired” based on 6 samples. As such, the Toms Brook watershed is not fully supportive of the Aquatic Life designated use. The VADEQ listed the probable cause of the benthic impairment as “unknown” (VADEQ, 2002a).

The Rapid Bioassessment Protocol II (RBP II) is the official protocol used to assess compliance with the general standard in Virginia. The RBP II procedure evaluates the benthic macroinvertebrate community by comparing individual network biomonitoring stations with reference biomonitoring stations. Reference biomonitoring stations have been identified by regional biologists that are both representative of regional physiographic and ecological conditions and have a healthy, unimpaired benthic community. Strait Creek, located in Highland County, Virginia, has been used as the reference watershed for Toms Brook. Of the ten assessments performed since October 1995, seven have received a rating of “moderately” impaired, as shown in Table 3.2.

Table 3.2. RBP II Scores for Toms Brook (TMB000.54)

RBP II (Scores calculated against a reference watershed.) **TMB000.54**

Sample Date	10/25/95	5/21/96	10/16/97	5/10/99	10/18/99	4/17/00	10/23/00	9/27/01	5/14/02	3/24/03	Average
a. RBP II Metric Values											
Taxa Richness	18	21	25	12	12	15	15	15	18	16	16.70
MFBI	5.67	5.42	4.88	5.06	4.27	5.29	4.44	4.43	6.33	4.98	5.08
SC/CF	0.38	0.41	0.37	0.23	0.18	0.10	0.10	0.90	0.30	2.00	0.50
EPT/Chi Abund	11.17	1.36	18.20	1.51	16.00	1.91	4.79	15.00	1.06	1.35	7.23
% Dominant	44.26	26.23	27.81	32.54	41.07	28.57	22.12	19.80	49.83	28.85	32.11
Dominant Species	Asellidae	Chironomida	Hydropsychi	Chironomida	Elmidae	Ephemerelli	Ephemerelli	Psephenida	Asellidae	Elmidae	
EPT Index	9	10	11	6	6	5	8	7	8	7	7.70
Comm. Loss Index	0.33	0.71	0.20	0.67	1.00	0.80	0.73	0.40	0.33	0.75	0.59
SH/Tot	0.01	0.01	0.02	0.01	0.00	0.01	0.03	0.00	0.00	0.03	0.01
Abundance	183	122	151	126	112	168	113	101	297	104	148
b. Reference Metric Values											
Station_ID	STC004.27	STC004.27	STC004.27	STC004.27	STC004.27	STC004.27	STC004.27	STC004.27	STC004.27	STC004.27	
Reference Sample Date											Average
Taxa Richness	19	27	17	18	21	20	19	15	19	20	19.50
MFBI	2.89	3.41	3.86	3.79	3.64	4.15	3.61	3.77	3.81	4.14	3.71
SC/CF	0.38	0.42	0.25	1.70	2.21	0.78	1.56	1.77	0.43	1.63	1.11
EPT/Chi Abund	74.00	6.46	63.00	4.87	29.00	3.80	20.00	35.00	7.64	1.68	24.54
% Dominant	21.30	17.27	28.30	20.66	25.23	16.00	25.23	24.11	20.00	32.26	23.04
EPT Index	10	17	9	11	10	12	12	9	11	12	11.30
Comm. Loss Index	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SH/Tot	0.14	0.26	0.05	0.17	0.15	0.11	0.05	0.04	0.26	0.11	0.14
Abundance	108	110	159	121	111	125	111	141	110	124	122
Reference Biological Score	46	48	46	46	46	48	46	46	46	44	46.20
c. RBP II Metric Ratios											
Taxa Richness	94.7	77.8	147.1	66.7	57.1	75.0	78.9	100.0	94.7	80.0	87.21
MFBI	51.0	62.9	79.1	74.9	85.3	78.5	81.3	85.3	60.1	83.1	74.14
SC/CF	97.9	98.2	146.0	13.4	8.1	13.2	6.2	50.9	69.0	123.1	62.61
EPT/Chi Abund	15.1	21.1	28.9	31.1	55.2	50.2	23.9	42.9	13.9	80.8	36.29
% Dominant	44.3	26.2	27.8	32.5	41.1	28.6	22.1	19.8	49.8	28.8	32.11
EPT Index	90.0	58.8	122.2	54.5	60.0	41.7	66.7	77.8	72.7	58.3	70.28
Comm. Loss Index	0.33	0.71	0.20	0.67	1.00	0.80	0.73	0.40	0.33	0.75	0.59
SH/Tot	7.9	3.1	39.5	4.8	0.0	5.3	49.1	0.0	1.3	25.5	13.65
d. RBP II Metric Scores											
Taxa Richness	6	4	6	4	2	4	4	6	6	4	4.6
MFBI	2	2	4	4	6	4	4	6	2	4	3.8
SC/CF	6	6	6	0	0	0	0	6	6	6	3.6
EPT/Chi Abund	0	0	2	2	4	4	0	2	0	6	2.0
% Dominant	0	4	4	2	0	4	4	6	0	4	2.8
EPT Index	4	0	6	0	0	0	0	2	2	0	1.4
Comm. Loss Index	6	4	6	4	4	4	4	6	6	4	4.8
SH/Tot	0	0	4	0	0	0	4	0	0	2	1.0
Total RBP II Score	24	20	38	16	16	20	20	34	22	30	24.0
% of Reference	52.17	41.67	82.61	34.78	34.78	41.67	43.48	73.91	47.83	68.18	52.1
RBP II Assessment[1]	**Moderate**	**Moderate**	**Slight**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Slight**	**Moderate**	**Slight**	

[1] RBP II Impairment Ratings: "Severe" 0-17; "Moderate" 21-50; "Slight" 54-79; "No Impact" 83-100.

The Macroinvertebrate Aggregated Index for Streams (MAIS) is a secondary index whose metrics are also calculated by VADEQ, but it is only used as a supplemental indicator of stream quality. The MAIS metrics were developed using data from the Central Appalachian Ridge and Valley ecoregion, and as such, are appropriate for use with Toms Brook watershed. Individual MAIS metrics are rated against a fixed scale rather than against those of a reference watershed, as in the RBP II index. The various metrics, some which duplicate those in the RBP II, along with their scores and final ratings, are given for each sample in Table 3.3. The MAIS assessment shows a periodic cycling of “Good” and “Poor” ratings, with an overall rating that is on the borderline between the good and poor ratings.

Table 3.3. MAIS Assessment Results for Toms Brook (TMB000.54)

a. MAIS Metric Values												**Best Score**
Sample Date	10/25/95	5/21/96	10/16/97	5/10/99	10/18/99	4/17/00	10/23/00	9/27/01	5/14/02	3/24/03	Average	**Category**
% 5 Dominant	78.69	76.23	69.54	85.71	86.61	85.71	70.80	66.34	87.54	84.62	79.2	<79.13
MFBI	5.67	5.42	4.88	5.06	4.27	5.29	4.44	4.43	6.33	4.98	5.1	<4.22
% Haptobenthos	45.36	37.70	71.52	44.44	88.39	59.52	61.95	69.31	24.58	61.54	56.4	>83.26
EPT Index	9.00	10.00	11.00	6.00	6.00	5.00	8.00	7.00	8.00	7.00	7.7	>7
# Mayfly Taxa	4.00	6.00	5.00	3.00	3.00	2.00	4.00	4.00	5.00	2.00	3.8	>3
% Mayfly Abundance	12.57	15.57	21.19	31.75	8.93	29.76	35.40	18.81	10.77	15.38	20.0	>17.52
Simpson's Diversity Index	0.77	0.86	0.88	0.82	0.77	0.83	0.88	0.90	0.71	0.84	0.8	>0.823
# Intolerant Taxa	13.00	14.00	18.00	7.00	8.00	7.00	8.00	12.00	11.00	9.00	10.7	>9
% Scraper Abundance	8.20	5.74	15.23	3.97	6.25	1.79	2.65	26.73	2.02	11.54	8.4	>10.7
b. MAIS Scores												
% 5 Dominant	2	2	2	1	1	1	2	2	1	1	1.5	
MFBI	0	1	1	1	1	1	1	1	0	1	0.8	
% Haptobenthos	0	0	1	0	2	1	1	1	0	1	0.7	
EPT Index	2	2	2	1	1	1	2	1	2	1	1.5	
# Mayfly Taxa	2	2	2	1	1	1	2	2	2	1	1.6	
% Mayfly Abundance	1	1	2	2	1	2	2	2	1	1	1.5	
Simpson's Diversity Index	1	2	2	1	1	2	2	2	1	2	1.6	
# Intolerant Taxa	2	2	2	1	1	1	1	2	2	1	1.5	
% Scraper Abundance	1	1	2	1	1	1	1	2	1	2	1.3	
Total MAIS Score	11	13	16	9	10	11	14	15	10	11	12.0	**18**
MAIS Assessment[1]	**Poor**	**Good**	**Good**	**Poor**	**Poor**	**Poor**	**Good**	**Good**	**Poor**	**Poor**		**Best**

[1] MAIS Ratings: "Very Poor" 0-6; "Poor" 7-12; "Good" 13-16; "Very Good" 17-18.

A qualitative analysis of various habitat parameters was conducted in conjunction with each biological sampling, beginning in 1995 for Toms Brook. The habitat parameter scores are given in Table 3.4. Each of the 10 habitat parameters has a maximum score of 20 indicating the most desirable condition, and a score of 0 indicating the poorest habitat conditions. In general, the habitat scores have been improving and received their highest score for the last sample.

Table 3.4. Habitat Evaluation Scores for Toms Brook (TMB000.54)

Habitat Metrics	10/25/95	05/21/96	10/16/97	05/10/99	10/18/99	04/17/00	10/23/00	09/27/01	05/14/02	03/24/03	Average
	Habitat Assessment Dates										
Channel Alterations	18	18	16	18	17	17	16	19	19	19	17.7
Bank Stability	16	14	16	19	13	15	18	20	18	16	16.5
Bank Vegetation	16	14	14	20	18	20	14	19	18	18	17.1
Embeddedness	12	12	14	8	9	2	8	9	10	16	10.0
Flow Quantity	20	20	20	19	18	17	19	16	18	19	18.6
Presence of Riffles	14	16	16	19	18	19	19	18	18	19	17.6
Riparian Vegetation Zone Width	8	6	8	19	18	13	12	16	19	17	13.6
Abundance of Bottom Sediment	14	14	14	7	15	15	17	12	13	18	13.9
Availability of Firm, Clean Channel Bottom Substrate	10	14	12	14	16	15	18	14	15	13	14.1
Velocity of Flow	14	14	14	10	13	14	17	10	10	16	13.2
Total Habitat Score[1]	142	142	144	153	155	147	158	153	158	171	152.3

[1] EPA Habitat Evaluation Ratings
(Bank Stability, Bank Vegetation, Riparian Vegetation Zone Width): Poor 0-5; "Marginal" 6-10"; "Sub-optimal" 11-15; "Optimal" 16-20
(All Other Metrics): "Poor" 0-5; "Marginal" 6-10"; "Sub-optimal" 11-15; "Optimal" 16-20

Virginia DEQ, with assistance from USEPA Region 3, is in the middle of a process to upgrade its biomonitoring and biological assessment methods to those currently recommended in the mid-Atlantic region. As part of this effort, a study has been performed to assist the agency to move from a paired-reference site approach to a regional reference condition approach, and has led to the development of a proposed stream condition index (SCI) for Virginia's non-coastal areas (Tetra Tech, 2002). This multimetric index is based on 8 biomonitoring metrics that are a different set than those used in the RBP II with a scoring range of 0 – 100. The maximum score of 100 represents the best benthic community sites. Current proposed threshold criteria would define "unimpaired" sites as those with an SCI > 61.9 (the 10th percentile of all scores from 62 reference sites in Virginia), and "impaired" sites as those with an SCI < 56.3 (the 5th percentile). The average SCI score for Toms Brook is 60 (Table 3.5), which falls in the grey boundary zone between "impaired" and "unimpaired" sites, and indicates that Toms Brook has a relatively minor impairment, in contrast with the RBP II test's "moderate" impairment rating. The average SCI score for Strait Creek is consistent with that of "unimpaired" sites.

Table 3.5. Stream Condition Index

Station ID	Stream	No. of Samples	Stream Condition Index		
			Minimum	Maximum	Average
TMDL Station					
TMB000.54	Toms Brook	10	49.4	71.5	60.0
Biological Reference Stations					
STC004.27	Strait Creek	10	67.6	82.2	76.8

Individual scores for the RBP II and SCI for Toms Brook are shown in Figure 3.4, together with SCI scores for Strait Creek – the biological reference station used for RBP II score comparisons for Toms Brook.

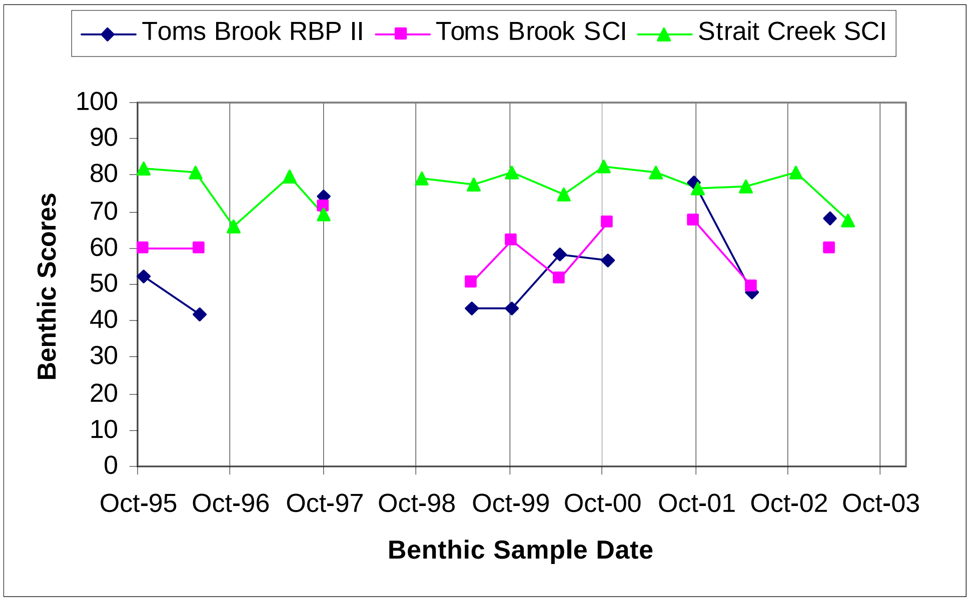


Figure 3.4. Benthic Index Scores

CHAPTER 4: BENTHIC STRESSOR ANALYSIS

4.1. Introduction

TMDLs must be developed for a specific pollutant. Since a benthic impairment is based on a biological inventory, rather than on a physical or chemical water quality parameter, the pollutant is not implicitly identified in the assessment, as it is with physical and chemical parameters. The process outlined in EPA's Stressor Identification Guidance Document (USEPA, 2000) was used to identify the critical stressor for Toms Brook. A list of candidate causes was developed from the listing information, biological data, published literature, and stakeholder input. Chemical and physical monitoring data provided additional evidence to support or eliminate the potential candidate causes. Biological metrics and habitat evaluations in aggregate provided the basis for the initial impairment listing, but individual metrics were also used to look for links with specific stressors, where possible. Volunteer monitoring data, land use distribution, point source Discharge Monitoring Report data, and visual assessment of conditions in and along the stream corridor provided additional information to investigate specific potential stressors. Logical pathways were explored between observed effects in the benthic community, potential stressors, and intermediate steps or interactions that would be consistent in establishing a cause and effect relationship with each candidate cause. The candidate benthic stressors considered in the following sections are temperature, pH, sediment, organic matter, nutrients, and toxics, including ammonia.

The results of the stressor analysis are divided into the following three categories:

- Non-Stressors: Stressors with data indicating normal conditions, without violations of a governing standard, or without observable impacts usually associated with a specific stressor. These stressors were eliminated from the list of possible stressors.

- Possible Stressors: Stressors with data indicating possible links, but with inconclusive data, were considered to be possible stressors.

- Most Probable Stressor(s): Stressor(s) with the most consistent data linking it with the poorer benthic metrics, or the most plausible of the possible stressors. This stressor(s) was selected as the most probable stressor(s) and was used for TMDL development.

4.2. Eliminated Stressors

Temperature

The water temperature appeared to fluctuate within normal bounds and has never exceeded Virginia's maximum water quality standard of 31°C for Class IV waters, as shown in Figure 4.1. The apparent lower variability during the past two years is the result of measurements only being taken during the spring and fall, rather than quarterly as in previous years. Temperature, therefore, does not appear to be a stressor.

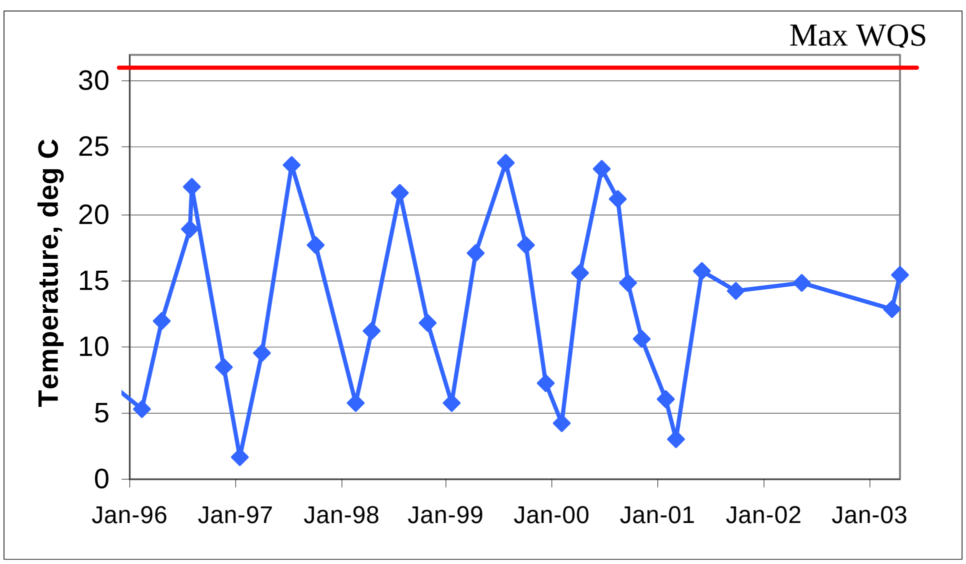


Figure 4.1. DEQ Ambient Water Temperature in Toms Brook

pH

All pH values fall between the Class IV water quality standard limits of 6.5 and 9.5, as shown in Figure 4.2. Alkalinity concentrations ($CaCO_3$) are fairly constant and within the range of groundwater criteria for the Valley and Ridge physiographic region (30-500 mg/L), as shown in Figure 4.3.

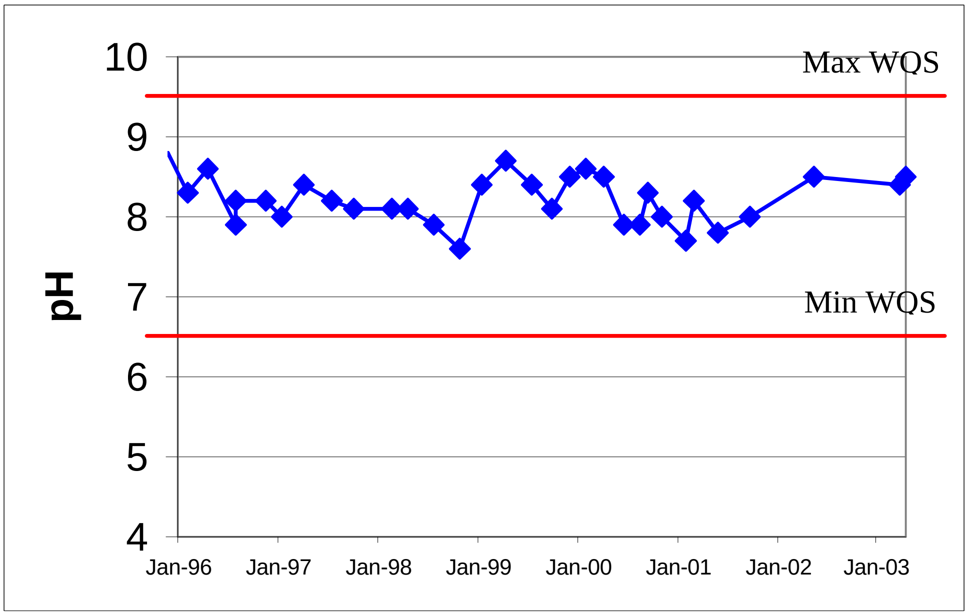


Figure 4.2. DEQ Field pH in Toms Brook

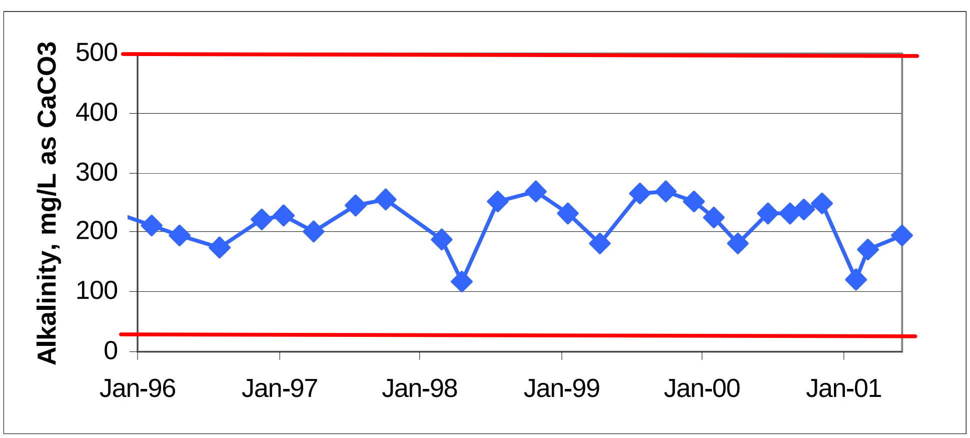


Figure 4.3. DEQ Ambient Alkalinity in Toms Brook

4.3. Possible Stressors

Sediment

Several factors provide evidence of potential impacts from sediment loading into Toms Brook. First, Toms Brook has consistently received moderate to low habitat scores for embeddedness – a measure of sediment in the interstitial spaces of the stream bed substrate where many benthic organisms live (Table 3.2). Second, the %Haptobenthos metric – a measure of benthic organisms that require a clean, coarse substrate - although historically at a moderate level, underwent a precipitous drop during the 5/24/02 sample, decreasing by a full 2/3 of its value. While this could be the result of increased sedimentation, it could also be related to toxicity.

On the other hand, the overall habitat scores have shown a gradually increasing trend, and are at the highest level they have ever been (Table 3.4). Some of the dominant species in past samples, such as *Hydropsychidae* and *Elmidae,* will not tolerate high sediment loads, and the species *Psephenidae* is not tolerant of high sediment levels.

One component of sediment that is measured regularly is total suspended solids (TSS), which measures suspended matter of either an inorganic (sediment) or organic nature. Monthly DEQ TSS concentrations have been primarily at or below the minimum detection limit (MDL) of analysis (3 mg/L), as shown in Figure 4.4. These measurements are only representative of ambient conditions, however, and do not capture the expected larger concentrations exhibited during storm runoff events.

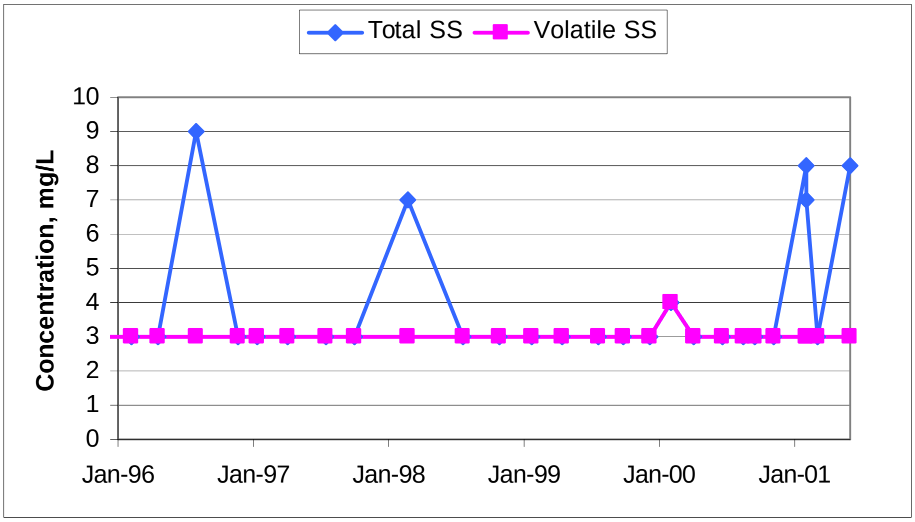


Figure 4.4. DEQ Ambient Suspended Solids Concentrations in Toms Brook

While DEQ and BSE samples were analyzed for TSS, suspended solids were reported as turbidity for FOSR samples. The 2003 suspended solids concentrations for various sites around the Toms Brook watershed are shown in Figure 4.5. Note the slightly elevated turbidity related to a March storm at the NS-13 site. The monthly FOSR measurements of STP effluent had comparable turbidity measurements averaging 3.45 NTU (range: 1.14–8.31 NTU). The 1995 to 2003 daily TSS concentrations reported on the STP bench sheets averaged 14.9 mg/L with a maximum of 196 mg/L. Since the STP discharge rate is small (<0.2 mgd and approximately 5% of Toms Brook baseflow) and there is considerable dilution, the daily TSS loads from the STP do not appear to be a significant source of sediment loadings to Toms Brook.

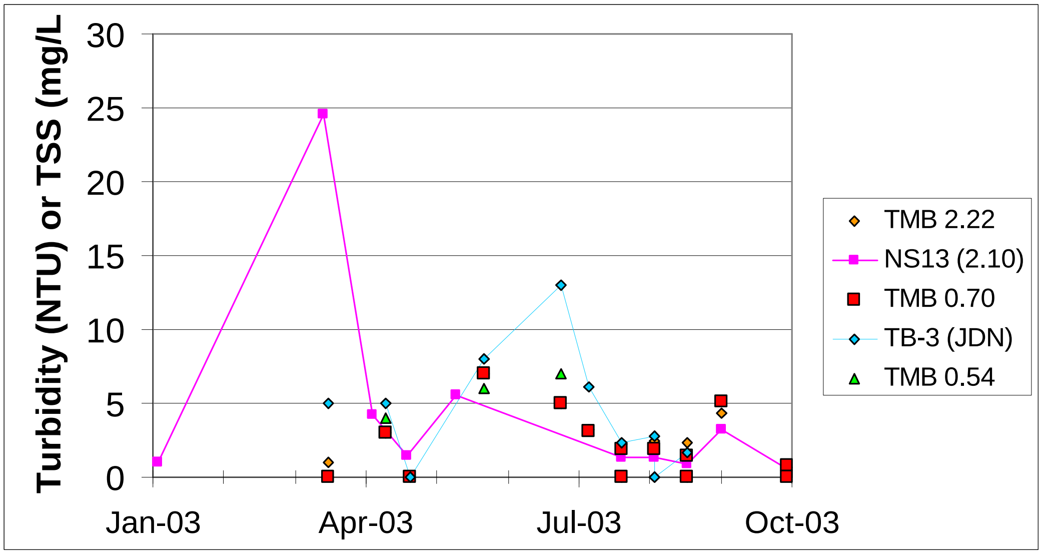


Figure 4.5. Suspended Solids at Various Toms Brook Monitoring Sites in 2003

(legend indicates stations from upstream to downstream by approximate river mile. Jordon Run (JDN) enters Toms Brook between the last two Toms Brook stations).

As another check on the plausibility of sediment as a stressor, three non-impaired watersheds in the region were area-adjusted to Toms Brook and modeled for sediment. The results of this preliminary modeling are shown in Table 4.1. Overall, one of the unimpaired reference watersheds produced a 29.5% larger sediment load and the other two produced smaller sediment loads, ranging from 11-18% less than the average annual load in Toms Brook. The sediment load for Toms Brook falls within the range of sediment loads from these three unimpaired watersheds, but produces a load greater than 2 of the 3 potential TMDL reference watersheds, indicating the possibility of a reduction in the health of the benthic community due to sediment.

Table 4.1. Preliminary Load Estimates Compared with 4 Reference Watersheds

	Toms Brook	Upper Opequon	Hays Creek	Strait Creek
Sediment	**5,676**	7,351	5,046	4,652
% > Toms Brook		29.5%	-11.1%	-18.0%
Nitrogen	**43,224**	53,509	28,116	25,600
% > Toms Brook		23.8%	-35.0%	-40.8%

Phosphorus	**20,446**	21,003	18,329	16,642
% > Toms Brook		2.7%	-10.4%	-18.6%

- Reference Loads less than Toms Brook

Toxics

Although in the early stages of the TMDL study toxicity was thought to be a possible stressor, additional data interpretation revealed that the benthic metrics did not support toxicity as a cause, so toxicity tests were not performed on fathead minnow and *Ceriodaphnia*, as in some other TMDL studies. Two sets of stream sediment samples from Toms Brook were previously analyzed for various metals and organic compounds, as shown in Table 4.2. Measured sediment concentrations of these toxic substances were compared to consensus-based probable effect concentrations (PEC; MacDonald et al., 2000) to determine if observed levels of toxics were sufficient to cause the benthic impairment. The PEC represents the concentration above which adverse effects are expected to occur more often than not in non-tidal waters. This approach is consistent with recent DEQ guidance on assessing the quality of the State's waters (DEQ, 2003).

Table 4.2. DEQ Sediment Toxics Data – Toms Brook

Parameter	ParamCode	1BTMB000.54 7/15/1992 9:15		1BTMB000.54 7/29/1996 10:10		Consensus-Based PEC
ALUMINUM, SEDIMENT (MG/KG AS AL DRY WGT	1108			7080		
ANTIMONY, SEDIMENT (MG/KG AS SB DRY WGT	1098			6		
ARSENIC, SEDIMENT (MG/KG DRY WT)	1003	263		5		33
BERYLIUM, SED (MG/KG AS BE DRY WT)	1013	5	U	5	U	
CADMIUM, SEDIMENT (MG/KG DRY WT)	1028	5	U	5	U	4.98
CHROMIUM, SEDIMENT (MG/KG DRY WT)	1029	26		15		111
COPPER, SEDIMENT (MG/KG AS CU DRY WT)	1043	1750		20		149
IRON, SEDIMENT (MG/KG AS DRY WT)	1170			14100		
LEAD, SEDIMENT (MG/KG AS PB DRY WT)	1052	60		18		128
MANGENESE, SEDIMENT (MG/KG AS DRY WT)	1053			406		
MERCURY, SEDIMENT (MG/KG AS HG DRY WT)	71921	0.3	U	0.3	U	1.06
NICKEL, SEDIMENT (MG/KG DRY WT)	1068	16		12		48.6
SELENIUM, SEDIMENT (MG/KG AS SE DRY WT)	1148	1	U	1	U	
SILVER, SEDIMENT (MG/KG AS AG DRY WT)	1078	5	U	5	U	
THALLIUM, SEDIMENT (MG/KG DRY WT)	34480	5	U	5	U	
ZINC, SEDIMENT (MG/KG AS ZN DRY WT)	1093	66		39		459
ALDRIN, SEDIMENT (UG/KG DRY WT)	39333	100	U	30	U	
CHLORDANE TECH MIX & METABS,SEDIMENT(U	39351	500	U	40	U	17.6
DDD, SEDIMENT (UG/KG DRY WT)	39363	100	U	20	U	28
DDE, SEDIMENT (UG/KG DRY WT)	39368	100	U	20	U	31.3
DDT, SEDIMENT (UG/KG DRY WT)	39373	100	U	30	U	62.9
DICOFOL (KELTHANE)	79799	100	U	80	U	
DIELDRIN, SEDIMENT (UG/KG DRY WT)	39383	100	U	20	U	61.8
ENDRIN, SEDIMENT (UG/KG DRY WT)	39393	100	U	30	U	207
HEPTACHLOR EPOXIDE, SED (UG/KG DRY WT)	75045	100	U	20	U	16
HEPTACHLOR, SEDIMENT (UG/L)	39413	100	U	20	U	
PCBS TOTAL,SEDIMENT (UG/KG DRY WT)	39526	500	U	30	U	676
PENTACHLOROPHENOL, SEDIMENT (UG/KG DR	39061	50	U	80	U	
TOXAPHENE, SEDIMENT (UG/L)	39403	1000	U	160	U	

U = analyzed, but not detected. Value is limit of detection.
PEC = probable effect concentration.

Of the 16 metals analyzed, 6 were not detected in either sample. Two metals (arsenic and copper) exceeded their corresponding consensus-based PECs in the 1992 sample, though both were detected at levels only slightly above their minimum detection levels (5 ppm) in 1996. Therefore, metal toxicity may have contributed to stress on benthic samples evaluated for the 1998 303(d) listing in Toms Brook, but it does not appear to be a current stressor. None of the 13 organic compounds analyzed for were detected in either sample set.

The benthic shredder population – organisms that process leaves and other coarse particulate matter - disappeared in two consecutive samples – 10/18/99 and 4/17/00, reappeared in the next two consecutive samples at low levels, disappeared again in the following 5/24/02 sample, and reappeared at a minimal level in the most recent sample. This behavior in the shredder population could be a toxic effect, but could result from other factors, such as excessive sedimentation or reductions in riparian vegetation. There did not appear to be any significant reductions in riparian vegetation, which leaves sedimentation as a possible alternative cause.

Chloride concentrations (Figure 4.6) are within the range or slightly higher than values typically found in streams, but they are not excessive and do not appear to be a major source of stress on the benthic community.

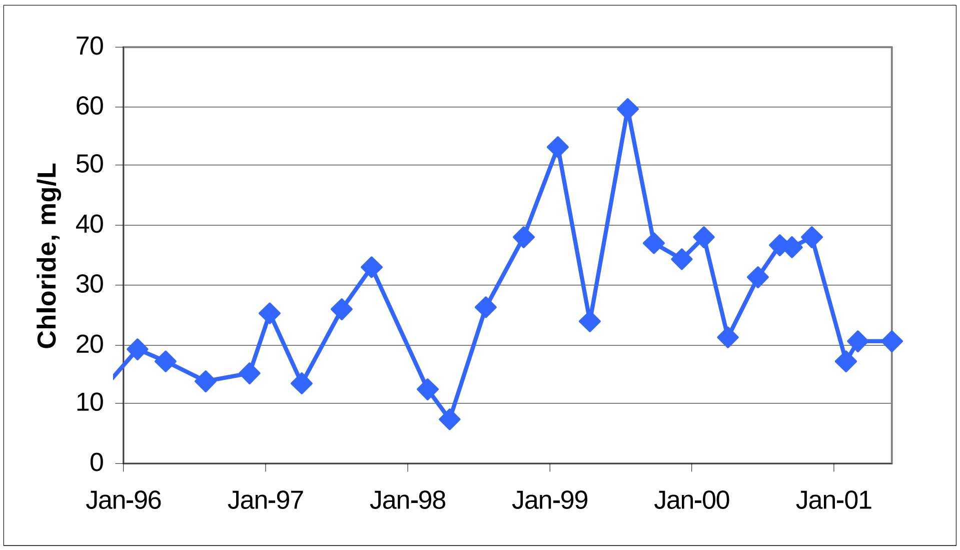


Figure 4.6. DEQ Reported Chloride Concentrations in Toms Brook (TMB000.54)

No violations of either the chronic or acute ammonia water quality standard were reported by DEQ prior to May 2001, when monthly ambient monitoring for ammonia was discontinued, as shown in Figure 4.7. The pH- and temperature-dependent ammonia standards for both acute and chronic conditions are also shown in the figure. The Toms Brook watershed includes one VPDES permitted industrial wastewater discharger – the Toms Brook Mauertown STP. Weekly volunteer monitoring by FOSR indicates one monitored exceedence of the STP's VPDES permitted ammonia concentration limit of 5.4 mg/L as shown in Figure 4.8.

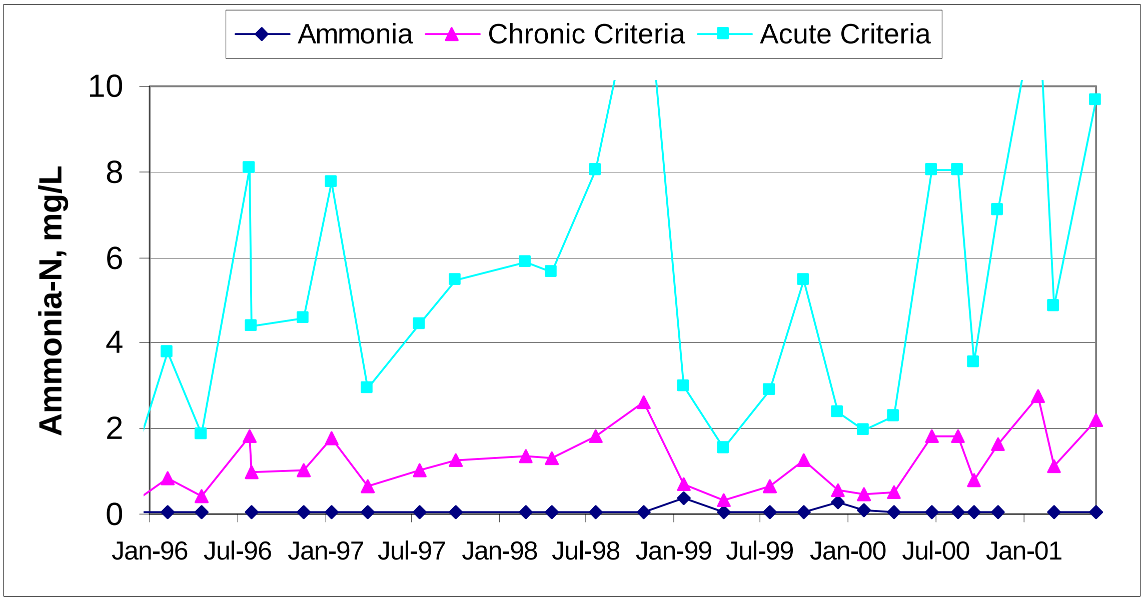


Figure 4.7. DEQ Reported In-Stream Ammonia Concentrations (TMB000.54)

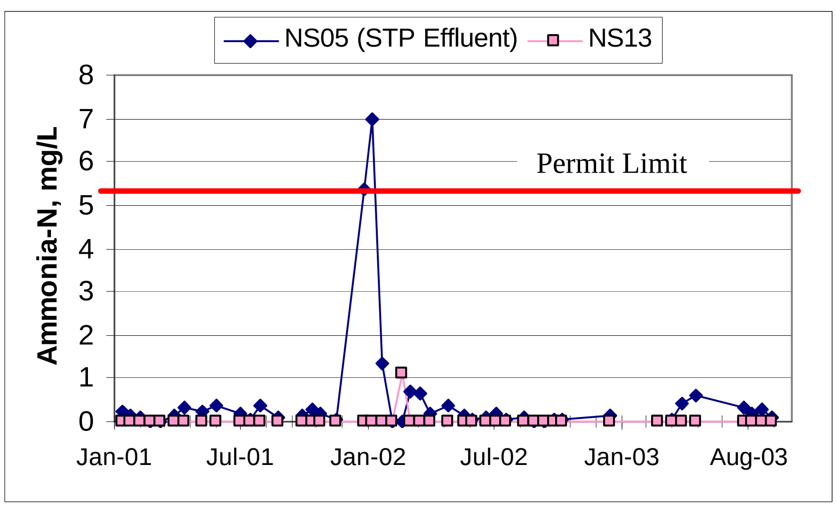


Figure 4.8. FOSR Reported Ammonia Concentrations

Ammonia measurements at various points in the Toms Brook watershed in 2003 are shown in Figure 4.9. All concentrations are relatively low with no water quality standard exceedence observed, though Jordon Run had several concentrations higher than Toms Brook. Corresponding measurements of ammonia-N in the monthly FOSR-monitored STP effluent during 2003 ranged from 0.05–0.62 mg/L, all well below the STP's permit limits.

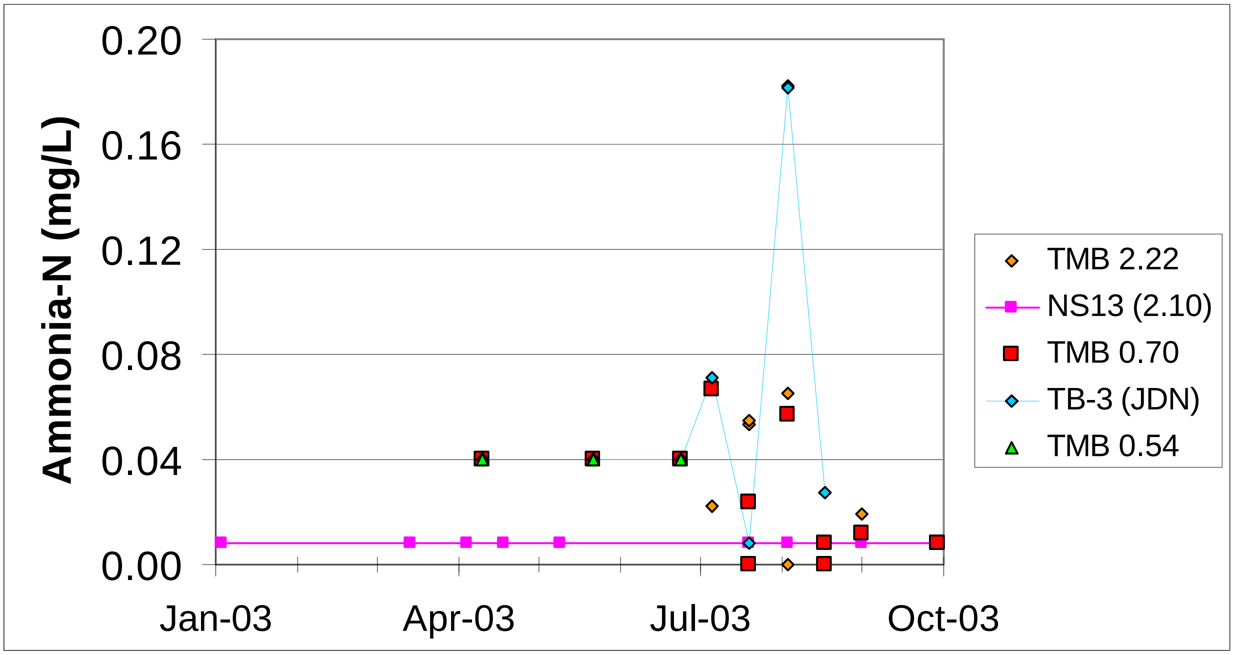


Figure 4.9. Ammonia-N at Various Toms Brook Monitoring Sites in 2003

The one volunteer-monitored exceedence of the STP permitted discharge limit in January 2002 was the primary motivation for searching further for possible permit exceedences by the STP. Consequently, when the monthly Discharge Monitoring Reports and daily bench sheet data were reviewed, additional exceedences were found. The DMRs indicated that the Toms Brook STP had 3 major process upsets on or about December 3, 1999, December 26, 2000 and December 25, 2001. The upsets lasted for varying periods of time, sometimes more than a month. Each of these documented upsets resulted in one or more exceedences of the STP's permitted ammonia concentration limit of 5.4 mg/L (Figure 4.10), and the first two upsets were also accompanied by increased BOD and TSS loadings as shown in Figure 4.11 and Figure 4.12, respectively.

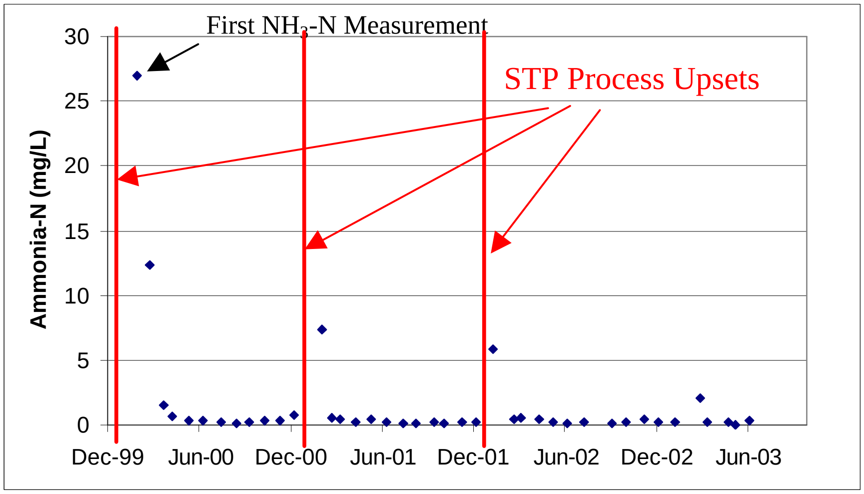


Figure 4.10. Toms Brook STP Ammonia Effluent Concentrations

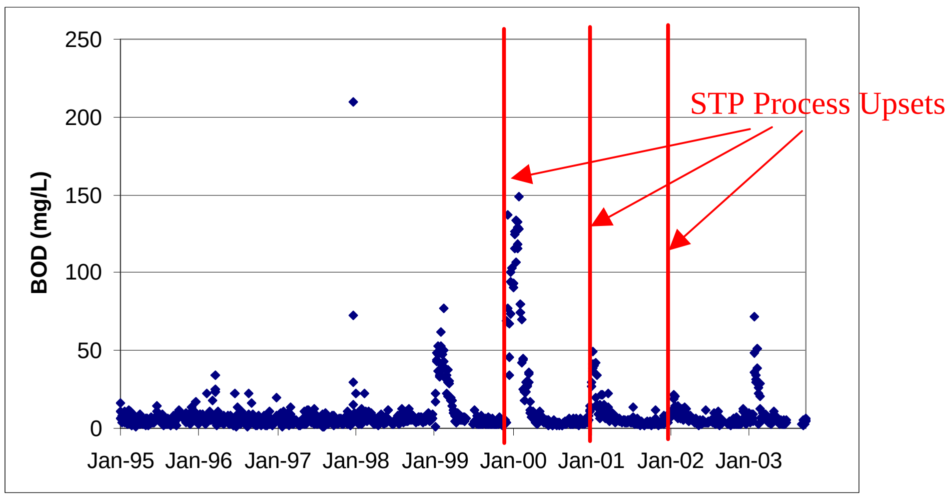


Figure 4.11. Toms Brook STP BOD Effluent Concentrations

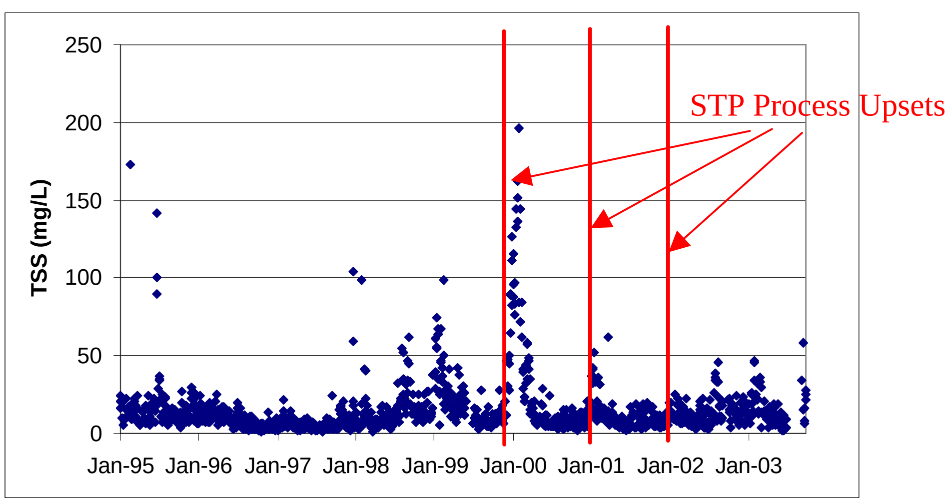


Figure 4.12. Toms Brook STP TSS Effluent Concentrations

Judging from the BOD and TSS graphs, the Toms Brook STP has had a history of winter-time process upsets over the past 5 or 6 years, though prior suspected ammonia violations are undocumented, as ammonia monitoring at the STP only began in January 2000. From documentation on the above 3 process upsets and other communications, the following possible causes of the upsets have been cited:

- Cold, wintry weather.
- Increased flow and salt loadings from a truck wash. The STP consultant has investigated this and found no evidence of upsets due to high salt levels.
- Reduced levels of mixed liquor suspended solids (MLSS). This has been addressed by arranging to haul MLSS sludge to the County's North Fork WTP allowing more frequent wasting of smaller amounts of sludge since 2000.
- Addition of landfill leachate and septage at varying rates. The plant stopped accepting landfill leachate in 2000. The STP also operates a septage receipt facility that may receive seasonal or periodic loads that add to the upset, e.g. vinegar from a former apple processing facility. Additional monitoring has been suggested to isolate the source(s), but nothing has been reported to-date.
- Filamentous growth due to surfactants, oil and grease, chlorides, and cold weather.
- A flow imbalance between parallel aeration tanks at the STP (investigated in 2001).
- High pH has been noted in the southern end of the sewage collection system, and highly variable alkalinity has been noted by DEQ personnel from the DMRs, but no source has been isolated. Measured pH at various sites in the watershed during 2003 are shown in Figure 4.13. The average pH of the STP effluent was 7.30 (range: 6.98 – 7.49), meets permit requirements, and is closer to neutral than other sites in the watershed.
- Stream too small to handle the STP flow and load. This issue was addressed during the special study conducted by DEQ by monitoring flow above the STP and at various other downstream sites, as shown in Table 4.3. The 7Q10 low flow condition used to develop the STP permit

conditions was 0.31 MGD (0.48 cfs). Under these low flow conditions, the STP has an instream wasteflow concentration of 37.9% when operating at the maximum design flow, and 26.0% when operating under average discharge conditions (using 2002 average daily STP flow). Permit limits developed for the STP are designed to protect aquatic life under this 7Q10 low flow condition. All of the plant upsets (when solids were lost and when ammonia discharges were above permit limits) occurred during high flow conditions in the winter when dilution potential would have been much greater than described above for low flow conditions. Sediment discharges from the STP were determined to be insignificant compared to non-point source loadings. Sediment (measured as TSS) discharges from the STP accounted for only 0.047% of the total Toms Brook average annual load.

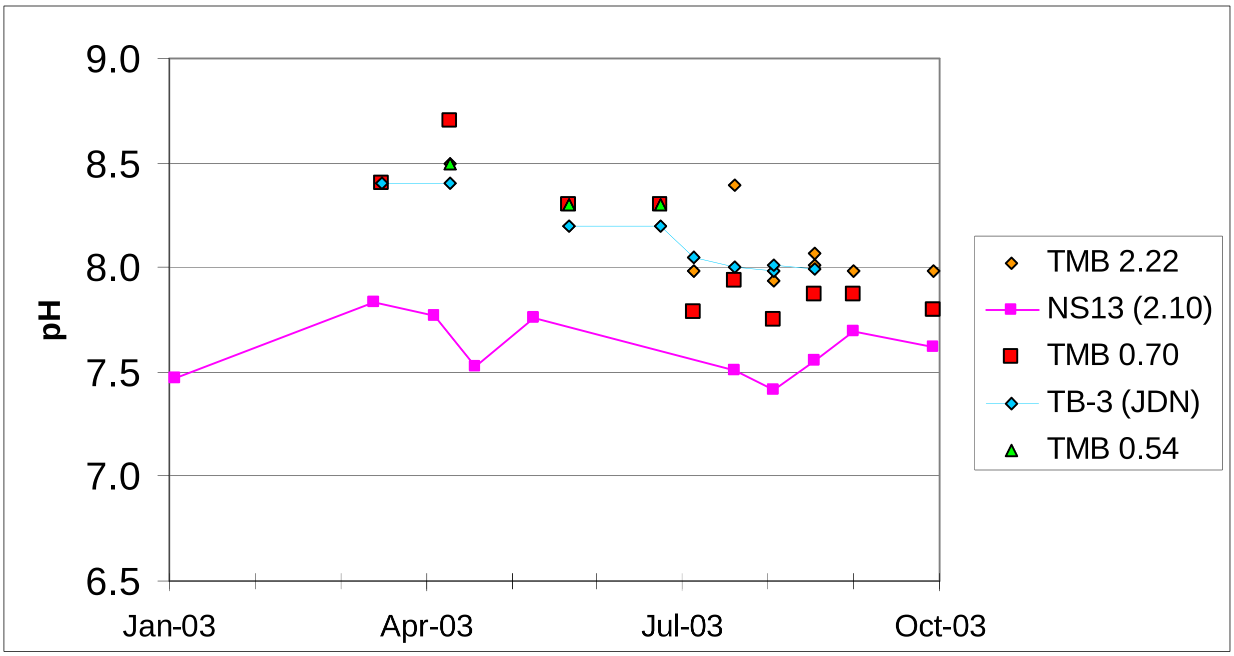


Figure 4.13. pH at Various Toms Brook Monitoring Sites in 2003

Table 4.3. Flow in Toms Brook Watershed – 2003 Special Study Measurements

DEQ Station	4/17/03 (cfs)	5/29/03 (cfs)	6/30/03 (cfs)	7/24/03 (cfs)	8/20/03 (cfs)	9/30/03 (cfs)	Average		Minimum	
							(cfs)	(MGD)	(cfs)	(MGD)
TMB002.22	15.90	9.06	7.78	4.29	3.37	8.62	8.17	5.28	3.37	2.18
JDN000.29	5.06	2.85	3.03	1.76	1.13	2.36	2.70	1.74	1.13	0.73
TMB000.70	20.60	12.40	9.68	5.81	4.95	10.60	10.67	6.90	4.95	3.20
TMB000.54	29.80	18.80	13.40	8.40	6.20	13.90	15.08	9.75	6.20	4.01

Potential toxicity was also investigated using STP bench sheet data from BOD tests on the plant effluent. Analysis of the effluent bench sheet data by Larry Hough, a regional DEQ engineer, for the months 01/02, 04/02, 08/02 and 01/03 found that the BOD tests exhibited signs of toxicity 40%, 15%, 0%, and 40% of the time, respectively. This indicates that there may be some unknown toxics in the STP effluent, but because of the high degree of dilution of the STP effluent by the flow in Toms Brook, it is unlikely BOD toxicity would be observed in Toms Brook itself. The associations between toxicity and declines in benthic health are difficult to judge, but toxics in the STP effluent, if they exist, appear to be more likely during cold weather. To follow up on the STP effluent toxicity question, the STP has arranged to have toxicity tests performed on the STP effluent near the end of August 2003, near the end of September, mid-December 2003, and mid-January 2004. The August test showed no toxicity, and the results are pending on the September sample. Neither of these is expected to show toxicity however, as December to January has been the historical problem period.

Prior to being aware of the previous two STP process upsets, the December 2001 STP process upset was considered to be related to the drop in benthic metrics between the 9/27/01 and 5/24/02 samples which bracket the upset date. Prior to the May 2002 sample, both the RBPII and MAIS total scores had shown gradual improvement over 5 samples between 1999 and 2001. Then between the fall 2001 and spring 2002 samples, 4 out of 8 metric scores decreased in the RBP II, and 6 out of 9 metric scores decreased in the MAIS index. After becoming aware of the earlier STP process upsets and looking for similar cause and effect relationships however, rather than finding negative impacts, the RBP II and MAIS scores actually increased between each set of samples that bracketed the STP upsets until the May 2002 sample. There was no sample taken in spring 2001 following the second upset, and there was no fall 2002 sample taken. There appears to be some indication that the fall scores are higher than the spring scores, but because samples were not taken on a regular schedule, it is difficult to determine if there was a seasonal impact. When reviewing the SCI and RBP II scores for Toms Brook shown in Figure 4.14, there appears to be a pattern of lower spring scores than those for the previous fall. These spring declines were initially suspected to be the result of the winter STP process upsets, however, the same pattern was observed in SCI scores at the reference site. Therefore, it is more likely that the lower spring scores are a natural seasonal effect, and not the result of the STP process upsets. The data therefore are inconclusive, although high ammonia concentrations from episodic STP process upsets are possible stressors to the Toms Brook benthic community.

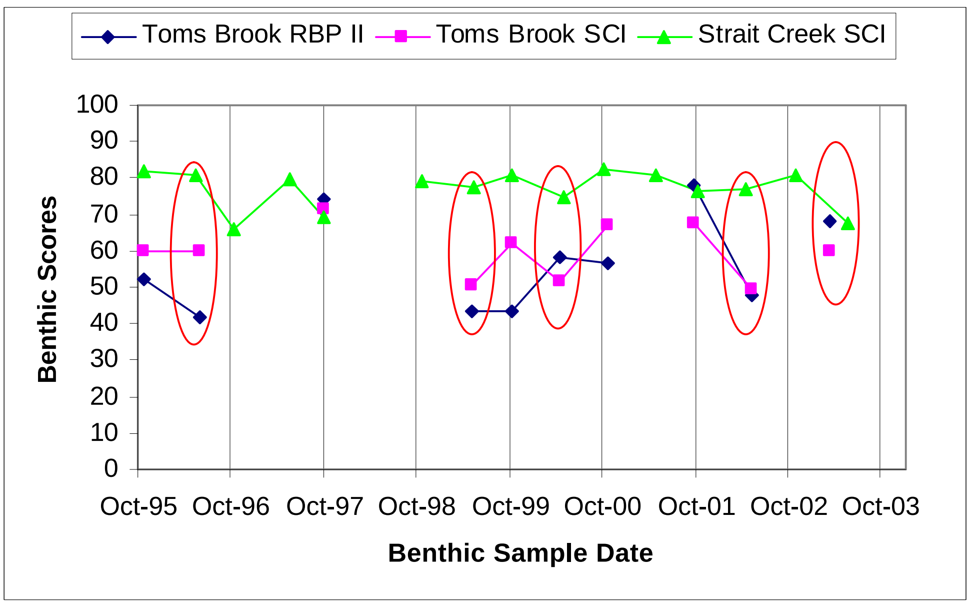


Figure 4.14. Highlighted Spring Index Scores

<u>Organic Matter</u>

Organic matter can affect water quality in either the dissolved or particulate form. Total organics would be reflected in increased concentrations of 5-day biological oxygen demand (BOD_5), total organic carbon (TOC), chemical oxygen demand (COD), and volatile solids, while particulate organics may be reflected in increased levels of volatile suspended solids (VSS). Decomposition of organic substances could result in decreased levels of measured dissolved oxygen (DO).

With respect to dissolved organics, all recent monthly BOD measurements by DEQ (Figure 4.15) were at or below their minimum detection limit (MDL) of 2 mg/L (1 mg/L before October 1997). DEQ-monitored monthly ambient DO concentrations (Figure 4.16) were all above the minimum ambient water quality standard of 5 mg/L. The FOSR volunteer data in Figure 4.17 indicated one upstream violation in February 2001 and showed generally high levels of DO in the STP effluent with a few exceptions (Toms Brook STP is not subject to a permitted DO limit). The difference in the range of DO measurements in Figure 4.17 from the ambient DEQ measurements in Figure 4.16 can be explained in one of several possible ways: the NS-13 station is upstream from the STP, while the DEQ ambient station is below the STP; the lower measurements in 2001-2002 were during an extended drought period, when the stream flow above the STP was likely to be extremely low; and the FOSR DO measurements were taken in the lab hours after sample collection, while DEQ ambient measurements were taken in the field at the time of sampling. The ambient DEQ data do not indicate any DO violations.

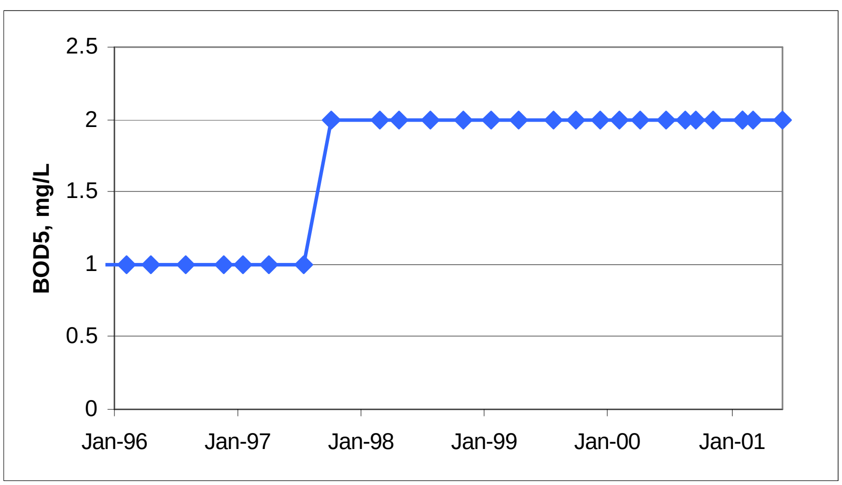


Figure 4.15. DEQ Monthly BOD_5 Concentration in Toms Brook (TMB000.54)

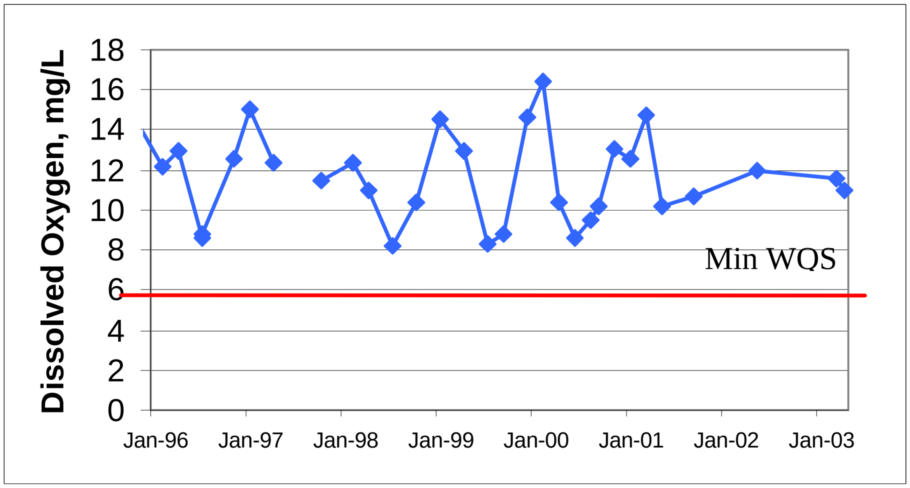


Figure 4.16. DEQ Monthly DO Concentration in Toms Brook (TMB000.54)

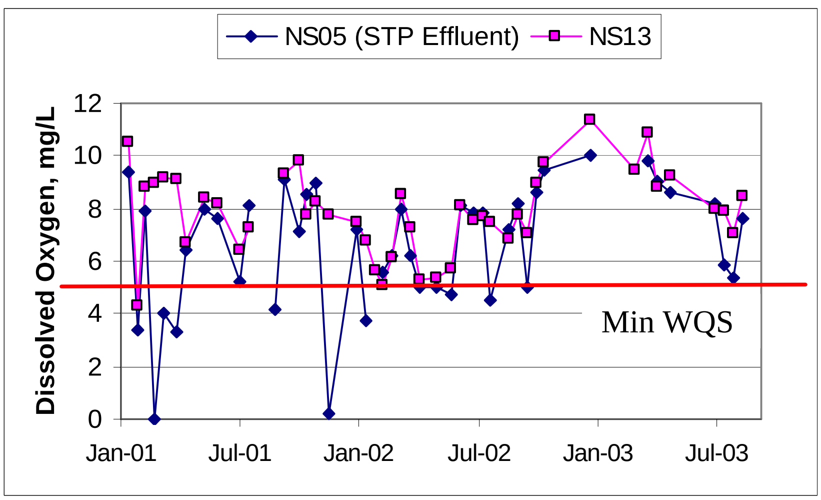


Figure 4.17. FOSR Dissolved Oxygen Concentrations

Monthly ambient DO concentrations at all sites in 2003 were all above the minimum ambient water quality standard (Figure 4.18). In 2003, all of the STP effluent measurements met the ambient water quality standard for dissolved oxygen, averaging 8.17 mg/L (range: 5.34 – 10.02 mg/L). As expected, DO at all sites tended to decrease during the summer months, due to warmer water temperatures.

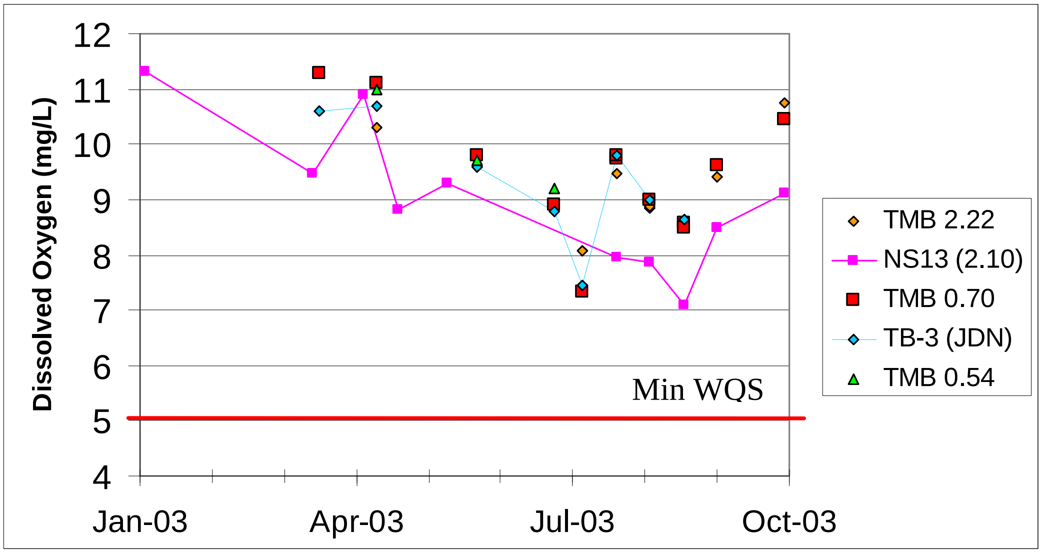


Figure 4.18. Dissolved Oxygen at Various Toms Brook Monitoring Sites in 2003

Concentrations of TKN were generally much lower than nitrate-N, generally indicating a low level of organic N, and consequently organics in the monthly stream samples, as shown in Figure 4.19.

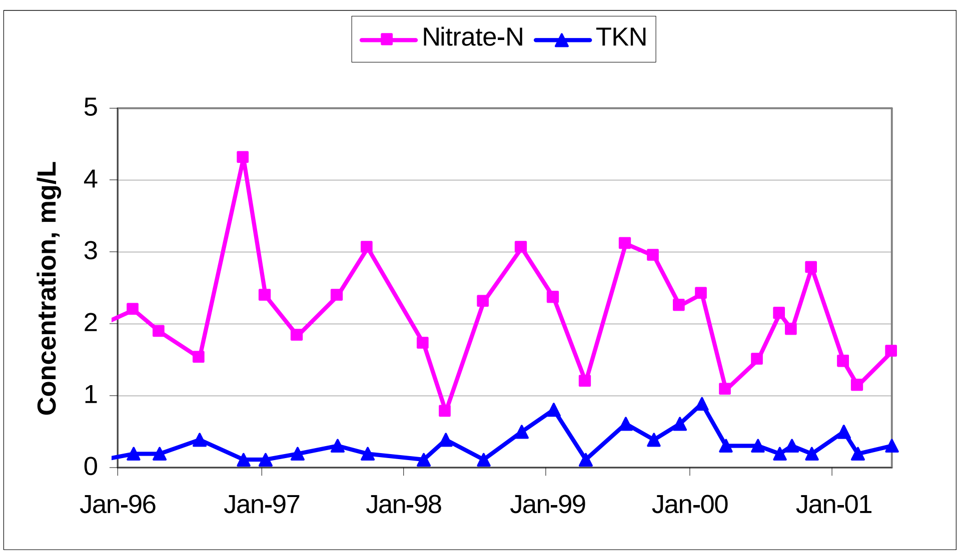


Figure 4.19. DEQ Monthly TKN and Nitrate-N Concentrations in Toms Brook (TMB000.54)

One of the benthic metrics – the MFBI metric – had an average score of 5.07 (good condition < 4.22; poor condition > 5.56), indicating moderate levels of organic matter (Table 3.2). Additionally, *Hydropsychidae* and *Chironimidae* - netspinners who thrive on fine detritus and algae - were the dominant benthic species in the 3 samples taken between 1996 and 1999 (Table 3.2), indicating that fine particulate organic matter in Toms Brook was plentiful at that time. Also, between the 9/27/01 sample and the 5/24/02 sample, the MFBI increased by 50%, the RBP II decreased by 39%, and *Asellidae* – an organism thought to be a "reliable indicator of zones where streams are beginning to recover from pollution by sewage" (Voshell, 2002) – increased from 12 to 148 organisms, becoming the dominant organism at that site (Table 4.4). Table 4.4 also shows that in the most recent benthic sample (3/24/03), *Asellidae* numbers had decreased back down to 15 at the TMB000.54 station, and were also seen at the first Toms Brook station upstream from its confluence with Jordon Run, TMB000.70, but not in the upstream station on Jordon Run – JDN000.29. This suggests that the pollution source causing the elevated *Asellidae* levels discharges to Toms Brook upstream of the confluence with Jordon Run.

Table 4.4. Dominant Organisms in Toms Brook

Dominant Organisms	**TMB000.54**						**TMB000.70**	**JDN000.29**
	10/18/99	**4/17/00**	**10/23/00**	**9/27/01**	**5/14/02**	**3/24/03**	**3/24/03**	**3/24/03**
Asellidae	6	25	10	12	148	15	14	
Chironimidae	3	32	14	3	50	17	20	14
Elmidae	46	22	17	10	33	30	16	93
Ephemerellidae	7	48	25		10	15	22	14
Psephenidae	7	3		20	4	11	25	2
Philopotamidae	24		14	17		2	2	
Total Organisms	**112**	**168**	**113**	**101**	**297**	**104**	**102**	**158**

Although there appears to be very low levels of organics indicated by monthly DEQ monitoring, other indicators show that the benthic community has responded in the past in ways that indicate a ready supply of organic material. The most recent increase in organics indicators between 9/27/01 and 5/24/02 corresponded with the latest STP process upset, and suggests that organics loading might be related to the periodic STP upsets. When looking at the first two documented upsets for similar trends, an increase was noted in the MFBI in the sample immediately after the December 1999 upset, while a spring sample was not taken following the December 2000 upset. But the large numbers of *Asellidae* seen after the third upset were not seen following the first two upsets. One possible explanation is that the organic loads from these upsets settled out of the water column and built up over time on the stream bottom, until a concentration or amount was reached that attracted the *Asellidae* to rapidly populate and dominate a previously healthy, balanced benthic community. Organic material, therefore, may be a possible stressor, but the available data is inconclusive.

<u>Nutrients</u>

Two metrics described in the organic matter section – high MFBI scores and dominance of *Hydropsychidae* and *Chironimidae* during certain samples (Table 3.2) – also indicate that nutrients might be a stressor. In addition, the reported 5-yr average dissolved N and P concentrations, 2.20 and 0.072 mg/L, respectively, are well above the N and P eutrophic sufficiency levels of 0.3 mg/L and 0.01 mg/L, respectively. DEQ monthly measurements of nitrate-N were shown previously in Figure 4.18 and measurements of orthophosphorus are shown in Figure 4.20. These elevated nutrient levels may facilitate primary production that is higher than normal for a second order stream. However, only one monthly measurement of total phosphorus (July 1999) exceeded DEQ's "threatened waters" threshold of 0.2 mg/L.

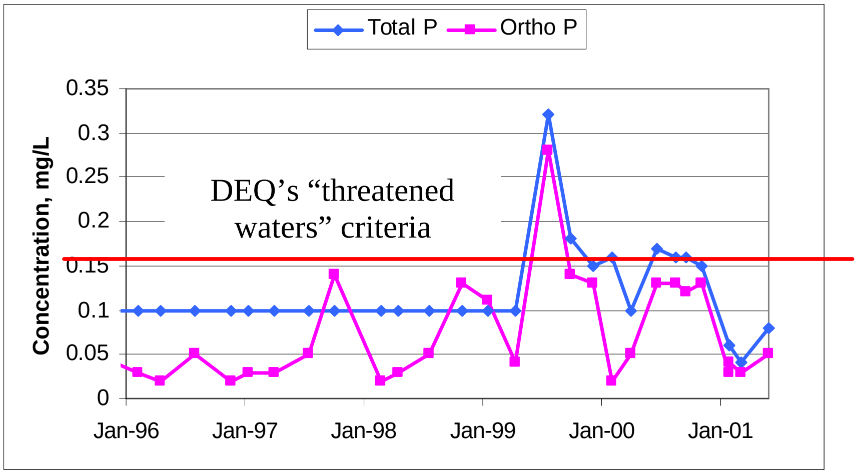


Figure 4.20. DEQ Monthly Orthophosphorus and Total Phosphorus in Toms Brook (TMB000.54)

Measurements of nitrate-N and orthophosphorus collected in 2003 at various sites in the Toms Brook watershed are shown in Figure 4.21 and Figure 4.22, respectively. Concentrations of nitrate and orthophosphorus in the Toms Brook STP effluent averaged 5.59 mg/L nitrate-N and 1.32 mg/L orthophosphorus. The STP effluent results in somewhat higher nutrient concentrations downstream of the STP, as can be seen by comparing concentrations at the downstream station (TMB000.54) and the two stations above the STP (TMB002.22 and NS13). The STP effluent appears to have a more pronounced effect on the nitrate levels than on orthophosphorus levels, as shown by the relative differences in upstream and downstream concentrations. During summer 2003, higher levels of nitrate were also seen in Jordon Run samples than upstream from the STP, while the several high readings of phosphate in late March were taken several days after a runoff event, with flow levels still elevated.

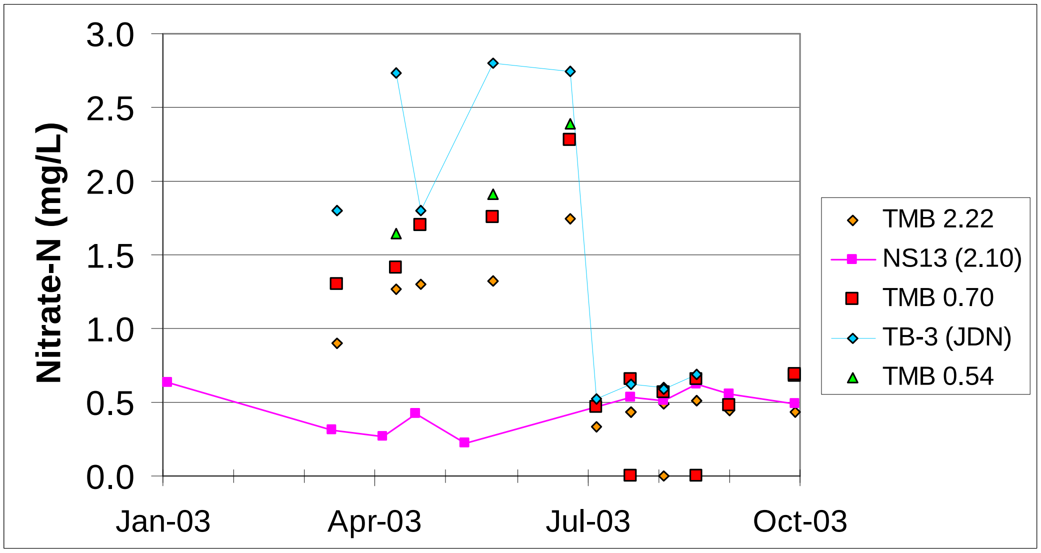


Figure 4.21. Nitrate-N at Various Toms Brook Monitoring Sites in 2003

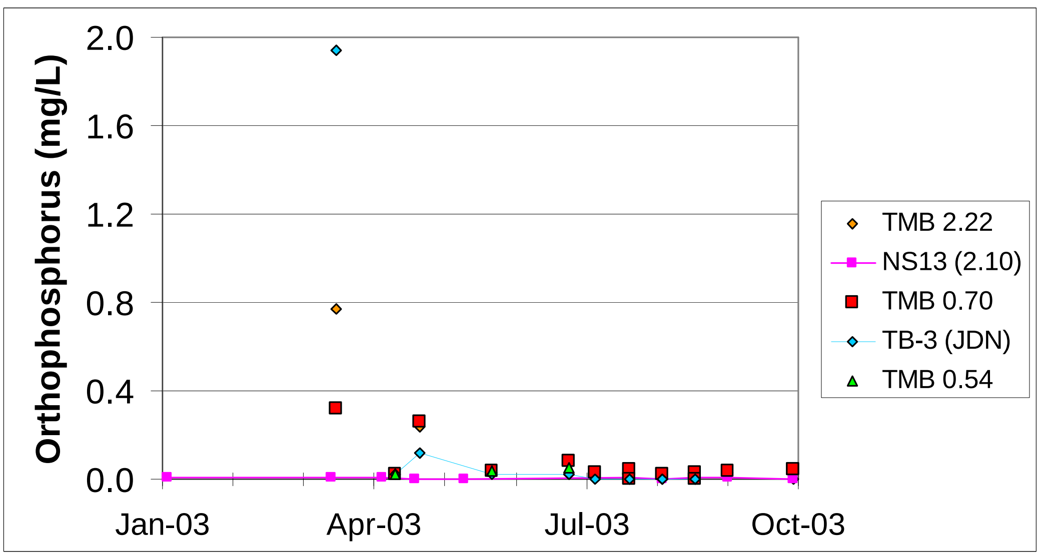


Figure 4.22. Orthophosphorus at Various Toms Brook Monitoring Sites in 2003

Both nutrients are dominated by their dissolved forms in Toms Brook, as shown in the previous figures and in data reported by DEQ in their periodic Sampling Inspection Reports of the STP, as shown in Table 4.5.

Table 4.5. STP Effluent Nutrient Concentrations from DEQ Sampling Inspection Reports

Date	Ortho-P (mg/L)	Total P (mg/L)	Nitrate-N (mg/L)	Total N (mg/L)
4/27/2000	3.88	4.7	16.7	18.9
11/15/2001	5.35	4.9	20.1	22.4

A diurnal dissolved oxygen (DO) test was performed by DEQ in August 2002. DEQ uses this test as an indicator of possible nutrient enrichment or excessive organics loadings. Observed DO readings ranged from a low of 6.49 to a maximum of 9.91, as shown in Figure 4.23. The difference between the daily maximum and minimum DO of 3.42 mg/L is in the low range compared to other impaired streams (3.08 – 5.79) that have recently had diurnal DO tests. An additional diurnal DO test conducted during September 2003 (Figure 4.24) exhibited the same trends and indicated that nutrient enrichment and organics loadings are not a problem.

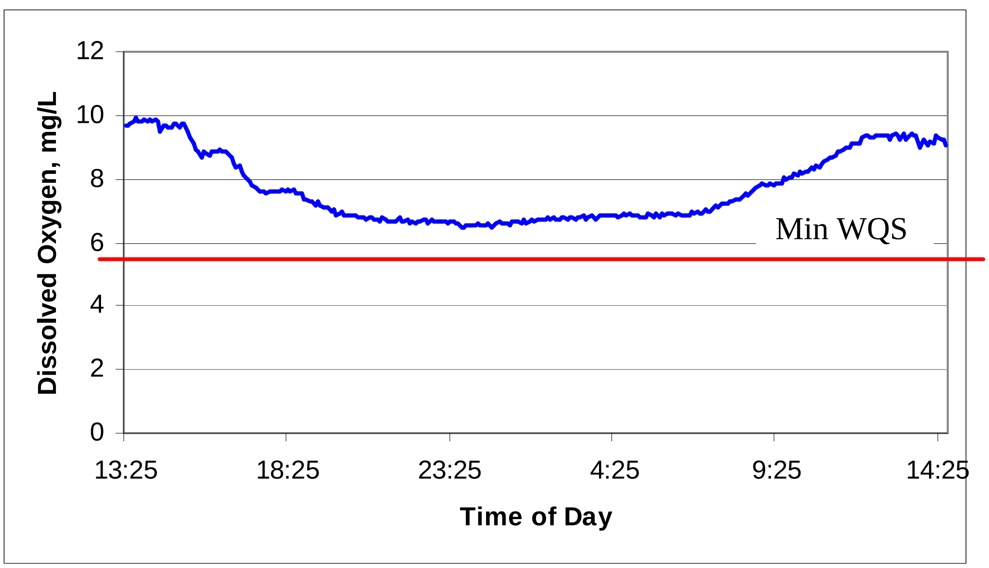


Figure 4.23. Toms Brook Diurnal Dissolved Oxygen, August 13-14, 2002

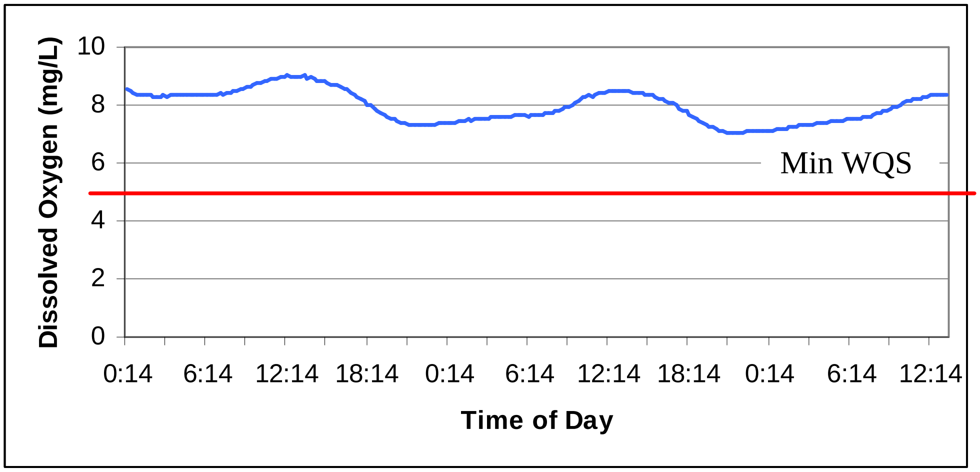


Figure 4.24. Toms Brook Diurnal Dissolved Oxygen, September 9-11, 2003

The preliminary modeling results shown previously in Table 4.1 showed that nutrient loads are slightly elevated and a possible stressor, but DO monitoring indicates that nutrients have not produced DO suppressions below water quality standards The Riparian Vegetation habitat score for Toms Brook, shown earlier in Table 3.4, had been in a low to moderate range prior to 1999, but has since moved into the high range with a lapse into the moderate range during the 5/24/02 sample. According to the Ohio EPA (1999), “wooded riparian buffers are a vital functional component of the stream ecotone and instrumental in the detention, removal and assimilation of nutrients from or by the water column”. Therefore, Toms Brook watershed appears to be improving with respect to its ability to reduce nutrient transport through surface runoff.

Low DO measurements, generally expected to accompany elevated levels of nutrients, have not been reported. However in the stream environment, nutrient enrichment and increased productivity may occur without corresponding low DO or high BOD concentrations, as occurs in lakes, due to natural re-aeration throughout riffle segments of the stream. In fact, subtle increases in nutrients will stimulate algae and macrophyte production which, in turn leads to increased DO. As long as stream flow is constant and temperatures are not excessively high, decaying organic matter will not necessarily cause a severe depletion of DO (Devlin, 2003). Nutrients were, therefore, considered to be a possible, but unlikely, benthic stressor in Toms Brook.

4.4. Most Probable Stressor

After analyzing the data collected from the various monitoring points around Toms Brook watershed, no single unambiguous stressor emerged during the stressor analysis. This is consistent with an earlier indication that the benthic impairment is relatively minor, and the total habitat scores have been steadily improving.

After discussion with state DCR and DEQ personnel, and with the regional biologist and TMDL coordinator, sediment was selected as the most probable stressor in Toms Brook. Sediment was chosen based on the following rationale:

- Chronic marginal to sub-optimal scores for embeddedness, moderate scores for the %Haptobenthos metric, the preliminary modeling results showing higher sediment loads from Toms Brook than 2 of 3 potential reference watersheds, and suspected larger sediment concentrations during runoff events which are not typically represented in DEQ's ambient monitoring data, are all consistent with a moderate impairment by sediment.

- Many best management practices (BMPs) employed to control sediment result in decreases in the other possible stressors (i.e., nutrients and organics) as well. Best management practices that might be used during implementation include those that would address the open canopy, streambank stability, riparian buffer zones, urban and construction runoff, livestock access to the stream, and runoff from agricultural fields. Some examples of the synergistic reductions from sediment BMPs are:

    - Reducing livestock access to streams also reduces inputs of organic matter (manure) and nutrients

    - Stream buffers reduce overland flow velocities, thus decreasing sediment transport capacity and transport of sediment-attached nutrients, as well as reductions in suspended sediment and organic matter.

- The perennial cold weather process upsets at the Toms Brook STP may contribute to the aggregate stress on the benthic community, but problems at the STP could not be definitively linked to the impairment. The cause of the STP upsets will continue to be investigated cooperatively by DEQ, the facility, and its consultants. In addition, operations and maintenance controls will continue to be implemented to avoid such upsets and to ensure continued compliance with all permitted ammonia, BOD, and TSS limits.

- The ultimate criteria for judging the success of the TMDL will be the restoration of the benthic community itself. As implementation proceeds, progress will be monitored, and the effectiveness of the implementation strategy will be evaluated.

In summary, it is the collective best professional judgment of the TMDL contractors and DEQ and DCR personnel that the Toms Brook TMDL should be developed and implemented for sediment. At the same time, DEQ will work with the Toms Brook – Mauertown Sanitary District STP to ensure continued compliance with its NPDES permit limits and to improve plant operation during cold weather. The frequency of plant upsets at the STP currently is below the threshold used by DEQ to warrant enforcement action, and the plant is considered to have addressed the largest upset in December 2000 with operational and maintenance modifications. Additional monitoring will be required and/or performed by DEQ during the critical December to January period to attempt to identify the source of the upsets, until such time as the problems are resolved, or to transfer these additional monitoring requirements to the STP’s permit during its next renewal application in 2004. If these actions are taken, we believe that this marginally impaired stream will be restored.

CHAPTER 5: THE REFERENCE WATERSHED MODELING APPROACH

5.1. Introduction

Because Virginia has no numeric in-stream criteria for the pollutant of concern, a “reference watershed” approach was used to set allowable loading rates in the impaired watershed.

The reference watershed approach pairs two watersheds – one whose streams are supportive of their designated uses and one whose streams are impaired. This reference watershed may or may not be the same as the biological reference watershed (i.e., the watershed used for determining comparative biological metric scores in the RBP II process). The reference watershed is selected on the basis of similarity of land use, topography, ecology, and soils characteristics with those of the impaired watershed. This approach is based on the assumption that reduction of the stressor loads in the impaired watershed to the level of the loads in the reference watershed will result in elimination of the benthic impairment.

The reference watershed approach involves assessment of the impaired reach and its watershed, identification of potential causes of impairment through a benthic stressor analysis, selection of an appropriate reference watershed, model parameterization of the reference and TMDL watersheds, definition of the TMDL endpoint using modeled output from the reference watershed, and development of alternative TMDL reduction (allocation) scenarios.

5.2. TMDL Reference Watershed Selection

5.2.1. Comparison of Potential Watersheds

The initial list of potential reference watersheds was composed of the watershed used as biological reference for Toms Brook (Strait Creek); the two watersheds used as sediment reference watersheds for the Blacks Run and Cooks Creek watershed TMDLs (Upper Opequon Creek and Hays Creek); another watershed in Shenandoah County that had been used as a biological reference (Stony Creek); and a watershed used as a reference for the benthically-impaired Stroubles Creek TMDL (Toms Creek). Because sediment was identified as the primary pollutant responsible for the benthic impairment, the comparison of watershed characteristics included not only geological and ecological characteristics, but also sediment-generating characteristics. Only minor differences exist among the ecoregion classifications for all of the potential reference watersheds. All watersheds are in the same Central Appalachian Ridges and Valleys Level III Ecoregion. Furthermore, all watersheds are in the Northern Limestone/Dolomite Valleys Level IV Ecoregion, with the exception of Toms Creek (TOM002.19), which is predominantly in the Southern Limestone/Dolomite Valleys and Low Rolling Hills Level IV Ecoregions.

Table 5.1 compares the various physical and sediment-related characteristics of the potential reference watersheds to the characteristics of the Toms Brook watershed. The characteristics chosen to be representative of sediment generation were land use distribution, non-forested average soil erodibility, and average non-forested % slope. The K-factor was used to represent soil erodibility in the watersheds, and was calculated as an area-weighted average of the soil K-factors in the watershed.

Table 5.1. Comparison of Physical and Sediment-Related Characteristics

						Non-Forested						Spring 2002 RBP II		
			Landuse Distribution			K-factor				Year 2000 Population				
Station ID	Stream Name	Area (ha)	Urban (%)	Forest (%)	Agr (%)	SSURGO	STATSGO	Slope (%)	Elevation (meters)	Non-Sewered	(pop/ha)	Score	% of Reference	SubEco Region
TMB000.54	Toms Brook	4,253	6%	45%	49%	0.32	0.32	7.62	303.8	1,110	0.26	22	47.8	67a
OPE034.53	Opequon Creek	15,123	5%	35%	60%	0.31	0.30	5.60	224.1	16,322	1.08	24	57.1	67a
STC004.27	Strait Creek	672	0%	71%	29%	NA	0.24	18.50	988.3	57	0.08	46	100	67a
STY004.24	Stony Creek	19,768	1%	87%	12%	0.26	0.27	11.67	507.7	2,126	0.11	10	23.8	67a
HYS001.41	Hays Creek	20,801	0%	52%	48%	0.31	0.31	12.53	526.2	1,600	0.08	36*	81.8	67a
TOM002.19	Toms Creek	9,070	2%	70%	28%	0.31	0.30	12.92	662.7	4,775	0.53	44**	100	67f

* Last sampled in Fall 2000. - Characteristics of the Impaired watershed

** Last sampled in Spring 2001. - Closest matching characteristics of the candidate reference watersheds

5.2.2. TMDL Reference Watershed Selection

Based on the information presented in the previous two sections, the Hays Creek watershed had the closest match with Toms Brook in terms of land use, K-factor, and population. Furthermore, Hays Creek had an average SCI score of 64.4, consistent with the current DEQ-proposed classification for benthically "unimpaired" streams (SCI > 61.9). Therefore, Hays Creek was selected as the TMDL reference watershed for Toms Brook. Hays Creek was also previously used as a reference watershed for the Cooks Creek TMDL.

5.3. TMDL Modeling Target Loads

For comparison of modeled sediment loads between the two watersheds, the model inputs for the TMDL reference watershed were area-adjusted so that loads would be generated from equal size watersheds. The reference watershed approach then defined the modeled sediment load from the non-impaired, area-adjusted Hays Creek watershed as the TMDL target endpoint for Toms Brook. Reductions from various sources are specified in the alternative TMDL scenarios that will achieve the TMDL target within the impaired Toms Brook watershed. Reductions in sediment load to levels found in the TMDL reference watershed are expected to allow benthic conditions to return to a non-impaired state.

CHAPTER 6: MODELING PROCESS FOR TMDL DEVELOPMENT

6.1. Source Assessment of Sediment

Sediment is generated in the Toms Brook watershed through the processes of surface runoff, streambank and channel erosion, as well as from background geologic forces. Sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, and urban land uses.

6.1.1. Surface Runoff

During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. This process is influenced by vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to washoff during rainfall events. The impact of sediment generated from impervious areas can also be influenced by the use of management practices, such as street sweeping, that reduce the surface load subject to washoff.

6.1.2. Channel and Streambank Erosion

Pasture areas accessible to streams are often associated with sediment loading through the activity of livestock on their streambanks. Livestock hooves on streambanks detach clumps of soil, and push the loosened soil downslope and into streams adjacent to these areas, delivering sediment to the stream independent of runoff events. Impervious areas tend to increase the percentage of rainfall that runs off the land surface leading to larger volumes of runoff with higher peak flows and greater channel erosion potential.

6.1.3. Point Source TSS Loads

Fine sediment is included in total suspended solids (TSS) loads that are permitted for various facilities with VPDES industrial discharge and stormwater permits, as well as contributions from single family homes included under the 1000-gpd general permit around the watershed.

6.2. GWLF Model Description

The Generalized Watershed Loading Functions (GWLF) model was developed for use in ungaged watersheds (Haith et al., 1992), and was chosen for the modeling required for the Toms Brook TMDL. The loading functions, upon which the model is based, are compromises between the empiricism of export coefficients and the complexity of chemical simulation models. GWLF is a continuous simulation spatially-lumped parameter model that operates on a daily time step. The model estimates runoff and sediment, dissolved and attached nitrogen and phosphorus loads delivered to streams from complex watersheds with a combination of point and non-point sources of pollution. The model considers flow inputs from both surface runoff and groundwater, and nutrient inputs from septic systems. The hydrology in the model is simulated with a daily water balance procedure that takes into consideration types of storages within the system. Runoff is generated based on the Soil Conservation Service's Curve Number method as presented in Technical Release 55 (SCS, 1986). Erosion is generated using a modification of the Universal Soil Loss Equation. Sediment supply uses a delivery ratio together with the erosion estimates, and sediment transport takes into consideration the transport capacity of the runoff. Stream bank and channel erosion was calculated using an algorithm by Evans (2002) as incorporated in the AVGWLF version (Evans et al., 2001) of the GWLF model.

The GWLF model operates on three input files for weather, transport, and nutrient data. The weather file contains daily temperature and precipitation for the period of simulation. The transport file contains primarily input data related to hydrology and sediment transport, while the nutrient file contains primarily nutrient values for the various land uses, point sources, and septic system types. The Visual Basic™ version of GWLF with modifications for use with ArcView was used in this study (Evans et al., 2001). The following additional modifications related to sediment were made to the Penn State Visual Basic version of the GWLF model, as incorporated in their ArcView interface for the model, AvGWLF v. 3.2:

- Urban sediment buildup was added as a variable input.
- Urban sediment washoff from impervious areas was added to total sediment load.
- Formulas for calculating monthly sediment yield by land use were corrected.
- Mean channel depth was added as a variable to the streambank erosion calculation.

6.3. Supplemental Post-Model Processing

After modeling was performed on individual and cumulative sub-watersheds, and total watersheds, the model output was post-processed in a Microsoft Excel™ spreadsheet to summarize the modeling results and to account for existing levels of agricultural best management practices (BMPs) implemented within the various sub-watersheds of Toms Brook watershed.

The effect of installed agricultural BMPs was based on the Virginia Department of Conservation and Recreation's State Cost-Share Database. This database tracks the implementation of BMPs within each state HUP watershed. These data are then used by EPA's Chesapeake Bay Program to calculate sediment reduction and pass-through fractions of the sediment load from each land use in each HUP for use with the Chesapeake Bay model and with the Virginia 2002 Statewide NPS Pollution Assessment (Yagow et al., 2002). Since Toms Brook lies within the B50 watershed, the sediment pass-through fractions for each land use category within B50 were related to, and applied to, the modeled land use categories used for this TMDL study. Modeled sediment loads within each land use category were then multiplied by their respective pass-through fractions to simulate the reduced loads resulting from existing BMPs.

6.4. Input Data Requirements

6.4.1. Climate Data

Hourly precipitation and temperature data were obtained for the National Weather Service station closest to Toms Brook – Woodstock (449263) - located about 3 miles from the watershed outlet, as shown in Figure 6.1. The periodic record was edited by filling missing records and distributing missing distributions based on available records from surrounding stations. The hourly precipitation data was summed as daily totals, and hourly temperature transformed to a daily average, with each converted to metric units, cm and °C, respectively, for use with the GWLF model.

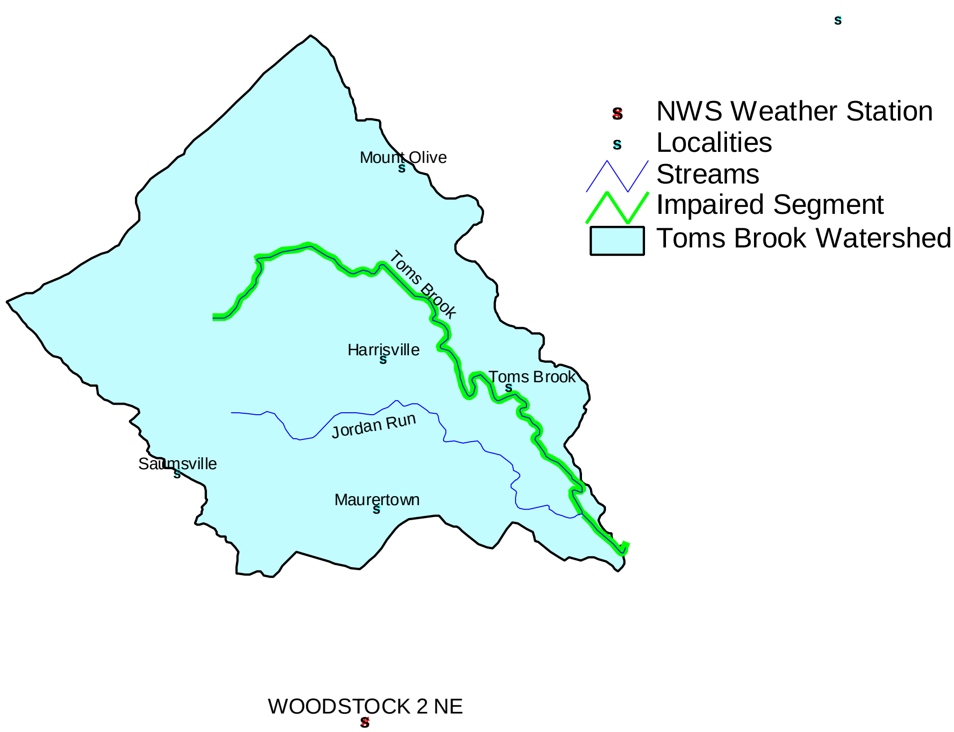


Figure 6.1. Location of Watershed and NWS Weather Station

6.4.2. Land Use

Digital NLCD land use for both Toms Brook and Hays Creek were obtained from the Multi-Resolution Land Classification (MRLC) project based on 1997 satellite imagery. As part of the 2002 Statewide Nonpoint Source Pollution

Assessment for the Virginia 305(b) Report, VADCR modified the MRLC land use categorization and included several derived land use categories to facilitate accounting for best management practice (BMP) implementation. The original MRLC land uses and their categorization by VADCR into 11 land use categories for modeling purposes are shown in Table 6.1. The 11 land use categories and their distribution within the Toms Brook and Hays Creek watersheds are shown in Table 6.2.

Table 6.1. Consolidation of VADCR Land Use Categories for Toms Brook

MRLC Code	Original MRLC Categories	Interim Groupings for Urban Area Calculations	Categories for DCR Load Calculations
11	open water		
92	emergent herbaceous wetlands		
42	evergreen forest	forest	forest
43	mixed forest		
41	deciduous forest		barren-disturbed forest*
91	woody wetlands		
81	pasture/hay	hay/pasture	pasture
			hay
			manure acres**
			pasture-cattle grazed**
			pasture-poultry litter**
82	row crops	row crops	high till cropland
			low till cropland
85	urban/recreational grasses	herbaceous urban (HERB)	
			pervious urban (PUR)
21	low intensity residential	low intensity urban (LO)	= 0.9*HERB + 0.6*LO + 0.15*HI
			+ 0.6*EXP
22	high intensity residential		
23	commercial/industrial/transportation	high intensity urban (HI)	
			impervious urban (IMP)
32	quarries/strip mines/gravel pits		= 0.1*HERB + 0.4*LO + 0.85*HI
31	bare rock/sand/clay	exposed (EXP)	+ 0.4*EXP
33	transitional		
	* Category derived from Department of Forestry database.		
	** Categories derived from county-based State NPS Assessment Surveys.		

Table 6.2. Land Use Distribution in Toms Brook and Hays Creek Watersheds

Land Use Category	Toms Brook (ha)	Hays Creek (ha)	Hays Creek Area-Adjusted (ha)
Hi-till cropland	59.8	60.3	12.3
Lo-till cropland	35.8	260.1	53.1
Hay	655.5	2,465.3	503.5
Pasture	878.4	5,949.5	1,215.2
Pasture-cattle grazed	339.5	1,306.7	266.9
Pasture-poultry litter	129.6	0.0	0.0
Manure acres	0.3	0.6	0.1
Forest	1,891.5	10,708.8	2,187.4
Disturbed forest	5.6	8.1	1.7
Pervious urban	150.2	18.0	3.7
Impervious urban	100.2	12.0	2.4
Total Area (ha)	**4,246.4**	**20,789.4**	**4,246.4**

6.4.3. Hydrologic Parameters

A long-term record of flow was not available for Toms Brook or any comparably-sized watershed in the area. Therefore, GWLF modeling was performed without attempting to calibrate hydrologic parameters. All parameters were evaluated in a consistent manner between the two watersheds, in order to ensure their comparability for the reference watershed approach. The GWLF parameter values were evaluated from a combination of GWLF user manual guidance, AVGWLF procedures, procedures developed during the 2002 statewide NPS pollution assessment (Yagow et al., 2002), and professional judgment. Parameters were generally evaluated using GWLF manual guidance, except where noted otherwise. Hydrologic and sediment parameters are all included in GWLF's transport input file, with the exception of urban sediment buildup rates, which are in the nutrient input file. The hydrologic parameters are listed below according to whether the parameters were related to the overall watershed, to the month of the year, or to individual land uses. A post-modeling check of model output with a limited number of observations showed that the modeled range of mean monthly flow over the 10-year simulation period (0.024 – 92.08 cfs) encompassed the observed flow range of 1.15 – 29.80 cfs measured over a 6-month period in 2003. A larger range of observed values would also be expected from a longer period of record with a wider variety of weather conditions. Therefore the calibration appears to be reasonable, producing output consistent with observed flows.

Watershed-Related Parameter Descriptions

- Unsaturated Soil Moisture Capacity (SMC): The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute - available water capacity.
- Recession coefficient (day^{-1}): The recession coefficient is a measure of the rate at which streamflow recedes following the cessation of a storm, and is approximated by averaging the ratios of streamflow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph.
- Seepage coefficient (day-1): The seepage coefficient represents the amount of flow lost as seepage to deep storage.

The following parameters were initialized by running the model for a 9-month period prior to the chosen period during which loads were calculated:

- Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone.
- Initial saturated storage (cm): Initial depth of water stored in the saturated zone.
- Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation.
- Antecedent Rainfall for each of 5 previous days (cm): The amount of rainfall on each of the five days preceding the first day in the weather file

Month-Related Parameter Descriptions

- Month: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model and its assumption that stored sediment is flushed from the system at the end of each Apr-Mar cycle. Model output was modified in order to summarize loads on a calendar-year basis.
- ET_CV: Composite evapotranspiration cover coefficient, calculated as an area-weighted average from land uses within each watershed.
- Hours per Day: Mean number of daylight hours.
- Erosion Coefficient: This is a regional coefficient used in Richardson's equation for calculating daily rainfall erosivity. Each region is assigned separate coefficients for the months October-March, and for April-September.

Land Use-Related Parameter Descriptions

- Curve Number: The SCS curve number (CN) is used in calculating runoff associated with a daily rainfall event, evaluated using SCS TR-55 guidance.

6.4.4. Sediment Parameters

Watershed-Related Parameter Descriptions

- Sediment delivery ratio: The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream, calculated as an inverse function of watershed size (Evans et al., 2001).

Land Use-Related Parameter Descriptions

- USLE K-factor: The soil erodibility factor was calculated as an area-weighted average of all component soil types.
- USLE LS-factor: This factor is calculated from slope and slope length measurements by land use. Slope is evaluated by GIS analysis, and slope length is calculated as an inverse function of slope.
- USLE C-factor: The vegetative cover factor for each land use was evaluated following GWLF manual guidance, Wischmeier and Smith (1978), and Hession et al. (1997).
- Daily sediment buildup rate on impervious surfaces: The daily amount of dry deposition deposited from the air on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.

Streambank Erosion Parameter Descriptions (Evans, 2002)

- % Developed land: percentage of the watershed with urban-related land uses – defined as all land in MDR, HDR, and COM land uses, as well as the imperviouos portions of LDR.
- Animal density: calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by the watershed area in acres.
- Stream length: calculated as the total stream length of natural stream channel, in meters. Excludes the non-erosive hardened and piped sections of the stream.
- Stream length with livestock access: calculated as the total stream length in the watershed where livestock have unrestricted access to streams, resulting in streambank trampling, in meters.
- Mean channel depth (m): calculated from relationships developed for the Chesapeake Bay Watershed Model by physiographic region, of the general form – $y = a * A^b$, where y = mean channel depth in ft, and A = drainage area in square miles.

6.5. Accounting for Sediment Pollutant Sources

6.5.1. Surface Runoff

Pervious area sediment loads were modeled explicitly in the GWLF model using sediment detachment, a modified USLE erosion algorithm, and a sediment delivery ratio to calculate edge-of-watershed loads, reported on a monthly basis by land use. Impervious area sediment loads were modeled explicitly in the GWLF model using an exponential buildup-washoff algorithm.

6.5.2. Channel and Streambank Erosion

Streambank erosion was modeled explicitly within the GWLF model using a modification of the routine included in the AVGWLF version of the GWLF model (Evans et al., 2001). This routine calculates average annual streambank erosion as a function of: percentage developed land, average area-weighted curve number (CN) and K-factors, watershed animal density, streamflow volume, bank height, and total stream length in the watershed.

6.5.3. Point Source

Sediment loads from VPDES point sources under existing conditions were calculated using monthly reported Discharge Monitoring Report (DMR) data. Daily loads were calculated as the monthly reported maximum average daily flow times the maximum average daily reported concentration. Average annual TSS loads were then calculated as the average of all previously calculated “daily loads” and multiplied times 365¼ days/year for the one permitted facility in Toms Brook watershed, as reported in Table 6.3.

Table 6.3. Existing TSS Loads in Toms Brook Watershed

		Existing TSS Loads		
PS Discharger	**VPDES_ID**	DMR Average Daily Flow (MGD)	DMR Average Daily [TSS] (mg/L)	Existing Average Load (t/yr)
Toms Brook STP	VA0061549	0.0972	18.06	2.425

Besides the Toms Brook-Mauertown STP, there is one permitted industrial stormwater discharger and 6 single family homes permitted under the 1000-gpd general permit in the watershed. Permitted TSS loads in Toms Brook watershed are shown in Table 6.4. Permitted loads for the industrial stormwater facility were calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 60 mg/L. Modeled runoff for the one industrial stormwater discharger was calculated by multiplying the maximum annual modeled runoff depth for urban pervious land uses (11.38 cm) and for urban impervious land uses (73.87 cm) by their respective percentages (60% pervious, 40% impervious) for an average annual runoff depth for commercial areas (36.38 cm). The load from each single family home unit was calculated as the maximum permitted daily flow and maximum TSS concentration allowed under this type of permit (1000 gpd and 30 mg/L). This translated into an annual TSS load of 0.0415 t/yr for each unit. The permitted total suspended solids (TSS) load for the Toms Brook –Mauertown STP was calculated based on its maximum permitted daily flow and average daily concentration.

Table 6.4. Permitted TSS Loads in Toms Brook Watershed

		Permitted TSS Loads					
PS Discharger	**VPDES_ID**	Drainage Area (acres)	Modeled Runoff (cm/yr)	Permitted Average Load (kg/day)	Permitted daily flow (MGD)	Permitted Ave Conc (mg/L)	Permitted Annual Load (t/yr)
Toms Brook STP	VA0061549				0.189	30	7.834
Industrial Stormwater							
RediMix Concrete	VAG110076	0.43	36.38			60	0.038
SFH General Permits							
	VAG401100				0.001	30	0.041
	VAG401123				0.001	30	0.041
	VAG401469				0.001	30	0.041
	VAG401368				0.001	30	0.041
	VAG401355				0.001	30	0.041
	VAG401427				0.001	30	0.041
Watershed Total							**8.121**

6.6. Accounting for Critical Conditions and Seasonal Variations

6.6.1. Critical Conditions

The GWLF model is a continuous simulation model that uses daily time steps for weather data and water balance calculations. The period of rainfall selected for modeling was chosen as a multi-year period that is representative of typical weather conditions for the area, and includes “dry”, “normal” and “wet” years. The model, therefore, incorporates the variable inputs needed to represent critical conditions during low flow – generally associated with point source loads – and critical conditions during high flow – generally associated with nonpoint source loads.

6.6.2. Seasonal Variability

The GWLF model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model also allows for monthly-variable parameter inputs for evapotranspiration cover coefficients, daylight hours/day, and rainfall erosivity coefficients for user-specified growing season months.

6.7. GWLF Model Parameters

The Generalized Watershed Loading Functions (GWLF) model was developed for use in ungaged watersheds (Haith et al., 1992), although hydrologic calibration has been recommended where observed flow data is available. However, since observed flow data was not available at Toms Brook or comparable neighboring watersheds, hydrologic calibration was not performed. Therefore, the GWLF model parameters were evaluated using GWLF user manual guidance and professional judgment. Since the reference watershed approach produces relative loads generated by the impaired and TMDL reference watersheds, the evaluation of each parameter was performed in the same manner for both watersheds to ensure the comparability of the model outputs.

A complete listing of all GWLF parameter values evaluated for the GWLF transport file for both watersheds under existing conditions are shown in Tables 6.5 – 6.7. Table 6.5 lists the various watershed-wide parameters and their values, Table 6.6 shows the evapotranspiration coefficients, and Table 6.7 shows the land use-related parameters – runoff curve numbers (CN) and the Universal Soil Loss Equation's KLSCP quotient for erosion modeling.

Table 6.5. GWLF Watershed Parameters

GWLF Watershed Parameters	units	Toms Brook	Hays Creek	Hays Creek Area-adjusted
recession coefficient	(day^{-1})	0.06	0.06	0.06
seepage coefficient	(day^{-1})	0	0	0
sediment delivery ratio		0.1476	0.0921	0.1476
unsaturated water capacity	(cm)	15.76	14.72	14.72
erosivity coefficient (Nov - Apr)		0.1	0.1	0.1
erosivity coefficient (growing season)		0.3	0.3	0.3
% developed land	(%)	2.4	0.1	0.1
no. of livestock	(AU)	540	2471	505
area-weighted soil erodibility		0.277	0.276	0.276
area-weighted runoff curve number		75.64	71.92	71.92
total stream length	(m)	18,892.2	151,387.3	30,922.0

Table 6.6. GWLF Monthly Evapotranspiration Cover Coefficients

Watershed	Apr	May	Jun	Jul*	Aug	Sep	Oct	Nov	Dec	Jan**	Feb	Mar
Toms Brook	0.939	0.951	0.955	**0.955**	0.955	0.942	0.852	0.762	0.723	**0.698**	0.826	0.914
Hays Creek	0.954	0.966	0.971	**0.971**	0.971	0.957	0.859	0.762	0.720	**0.693**	0.832	0.926
Hays Creek Area-adjusted	0.954	0.966	0.971	**0.971**	0.971	0.957	0.859	0.762	0.720	**0.693**	0.832	0.926

* July values represent the maximum composite ET coefficients during the growing season.
** Jan values represent the minimum composite ET coefficients during the dormant season.

Table 6.7. GWLF Land Use Parameters – Existing Conditions

Land Use	Toms Brook		Hays Creek		Hays Creek Area-Adjusted	
	KLSCP	CN	KLSCP	CN	KLSCP	CN
Hi Till	0.9207	85.6	1.4412	83.9	1.4412	83.9
Low Till	0.4054	83.7	0.6346	82.0	0.6346	82.0
Hay	0.0379	77.1	0.0645	75.0	0.0645	75.0
Pasture	0.0379	77.9	0.0645	75.5	0.0645	75.5
Pasture-cattle grazed	0.0379	77.9	0.0645	75.5	0.0645	75.5
Pasture-poultry litter	0.0379	77.9	0.0645	75.5	0.0645	75.5
Manure Acres	0.0000	98.0	0.0000	98.0	0.0000	98.0
Forest	0.0029	71.6	0.0042	68.4	0.0042	68.4
Disturbed Forest	0.9028	90.5	1.1680	89.4	1.1680	89.4
Pervious Urban	0.0085	77.9	0.0098	75.5	0.0098	75.5
Impervious Urban	0.0000	98.0	0.0000	98.0	0.0000	98.0

CHAPTER 7: THE BENTHIC TMDL FOR SEDIMENT

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1994).

7.1. Background

The benthic TMDL for sediment was developed using a reference watershed approach. The GWLF model was run for existing conditions over the 11-yr period of April 1984 – March 1995, and then summarized over the 10 included calendar years (January 1985 – December 1994). This period was chosen to include a variety of hydrologic conditions that included both wet and dry years. Since different size watersheds would be expected to produce different size sediment loads, the area of the impaired watershed was adjusted to the area of the impaired watershed by multiplying the ratio of the watershed areas times the area of each land use in the impaired watershed, so that model output was compared between two equal-sized watersheds. The average annual sediment load (t/yr) from Hays Creek (the TMDL reference watershed), area-adjusted to the impaired watershed, was then used to define the TMDL sediment load for the impaired Toms Brook watershed.

In order to provide more information on the spatial variability of the sediment loads for the implementation phase, the entire Toms Brook watershed was subdivided into 3 sub-watersheds, as shown in Figure 7.1. Modeling was performed on these 3 sub-watersheds plus the area-adjusted Hays Creek watershed. The TMDL reference watershed was modeled as a single watershed. The increased spatial variability of sediment sources by land use and sub-area in the impaired watershed is important when defining where and how reductions are made for the allocation scenarios and during future planning for implementation of control measures.

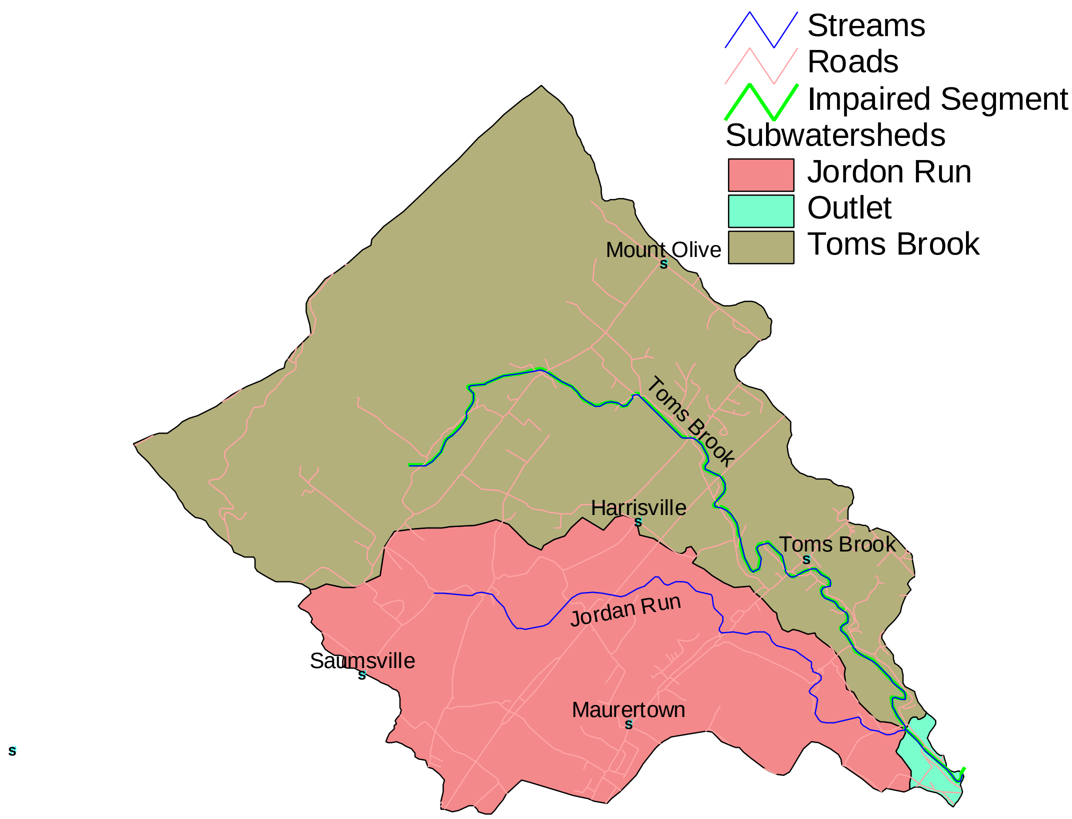


Figure 7.1. GWLF Modeling Subwatersheds for Toms Brook

Of the 3 sub-watersheds in the Toms Brook watershed, 2 sub-watersheds originate with headwater segments, while the remaining downstream sub-watershed receives flow and sediment from both of the upstream sub-watersheds. Because the GWLF model was not designed to model a downstream subwatershed independently, the downstream watershed was modeled to include all of its upstream drainage. Spreadsheet accounting was then used to subtract loads from upstream segments and to account for differences in the GWLF area-based sediment delivery ratio between the entire watershed and smaller upstream subwatersheds, thereby apportioning watershed sediment loads among the various subwatersheds. In order to focus on the comparison between the impaired and reference watershed, all loads in the following discussion are reported only as watershed totals for the impaired Toms Brook watershed and its area-adjusted TMDL reference watershed – Hays Creek. Details on model parameter inputs and sediment loads for all of the individual subwatersheds are given in Appendix B.

7.2. The Toms Brook Benthic TMDL

The benthic TMDL for the Toms Brook watershed was developed using sediment as the pollutant and a reference watershed approach, with Hays Creek watershed as the TMDL reference watershed. Since Hays Creek watershed was larger than the Toms Brook watershed, the area of each land use in the Hays Creek watershed was decreased in proportion to the ratio of the area of the impaired watershed to that of the TMDL reference watershed (x 0.2043), as detailed in Table 6.2. This resulted in an area-adjusted Hays Creek watershed equal in size with the land area in the impaired Toms Brook watershed (4,246.4 ha).

The existing sediment loads were modeled for each watershed and are listed in Table 7.1 by sediment source as average annual (t/yr) and unit-area (t/ha) loads. The target TMDL sediment load in Toms Brook – 4,866.0 t/yr - was defined as the average annual sediment load for the area-adjusted Hays Creek watershed under existing conditions.

Table 7.1. Existing Sediment Loads (t/yr)

Surface Runoff Sources	Toms Brook (t/yr)	(t/ha)	Area-adjusted Hays Creek (t/yr)	(t/ha)
High Till	1,974.2	32.7	325.1	26.4
Low Till	466.3	1.8	1,015.0	19.1
Pasture	2,007.8	0.2	3,325.1	0.3
Forest	316.9	0.0	196.9	0.0
Pervious Urban	35.4	2.0	0.9	0.3
Impervious Urban	40.8	3.4	1.0	0.4
Other Sources				
Channel Erosion	259.5		2.0	
Point Sources	2.4		0.0	
Watershed Totals	**5,103.4**		**4,866.0**	
		Target Sediment TMDL Load =	**4,866.0**	**t/yr**
		10% MOS =	486.6	t/yr
		Load for Allocation =	**4,379.4**	**t/yr**

The benthic TMDL for Toms Brook is comprised of three required load components – the waste load allocation (WLA) from point sources, the load allocation (LA) from nonpoint sources, and a margin of safety (MOS), as shown in Table 7.2.

Table 7.2. Toms Brook TMDL Sediment Load

TMDL (t/yr)	WLA (t/yr)	LA (t/yr)	MOS (t/yr)
4,866.0	8.1	4,371.3	486.6
	VA0061549 = 7.83 VAG110076 = 0.04 SFH General Permits = 0.25		

The margin of safety (MOS) was explicitly defined as 10% of the calculated TMDL to reflect the relative uncertainty associated with benthic impairments. The waste load allocation (WLA) was calculated as the permitted TSS load from all permitted sources. The load allocation (LA) – the allowable sediment load from nonpoint sources – was calculated as the target TMDL load minus the MOS minus the WLA. Since the MOS is excluded from allocation, the target load for modeling purposes in Toms Brook becomes the TMDL minus the MOS (4,379.4 t/yr).

Because future land use change in the watershed was considered to be minimal, TMDL modeling for the allocation runs was performed using the existing land use in Toms Brook. TMDL allocation scenarios were developed by consolidating nonpoint source loads into 3 categories – agriculture, urban, and forestry – and then comparing category loads from the Toms Brook watershed to those of its area-adjusted reference watershed – Hays Creek. These categorized loads and the reductions from several alternative scenarios required to meet the TMDL are shown in Table 7.3.

Table 7.3. TMDL Allocation Scenarios for Toms Brook

Source Category	Reference Hays Creek (t/yr)	Existing Toms Brook (t/yr)	Toms Brook TMDL Sediment Load Allocations					
			TMDL Alternative 1		TMDL Alternative 2		TMDL Alternative 3	
			(% reduction)	(t/yr)	(% reduction)	(t/yr)	(% reduction)	(t/yr)
Agriculture	4,665.2	4,448.4	**14.3%**	3,812.1	**14.5%**	3,802.4	**15.1%**	3,776.4
Urban	1.9	76.2	**14.3%**	65.3	0%	76.2	0%	76.2
Forestry	196.9	316.9	**14.3%**	271.6	**14.5%**	270.9	**10.0%**	285.2
Channel Erosion	2.0	259.5	**14.3%**	222.4	**14.5%**	221.8	**10.0%**	233.5
Point Sources	0.0	2.4	0%	8.1	0%	8.1	0%	8.1
Total	**4,866.0**	**5,103.4**		**4,379.4**		**4,379.4**		**4,379.4**

In each of the allocation scenarios, an increase was given to point sources, as this load represents the load corresponding to its permit conditions. TMDL Alternative 1 is achieved by taking equal percent reductions from all other sources. Since the urban load is less than 2% of the total sediment load, TMDL Alternative 2 is achieved without reducing the urban load and requires equal percent reductions from the remaining 3 source categories. TMDL Alternative 3 is achieved by taking a larger percent reduction from the largest source category – Agriculture – and a smaller, equal percent reduction from the remaining two source categories. Concerns were expressed both at the final public meeting and in follow-up comments that equal % reductions should be required from all categories. Alternative 1 best addresses these concerns and is, therefore, recommended as the TMDL allocation scenario to use as a starting point for implementation planning.

7.3. Summary

The benthic TMDL for Toms Brook was developed using sediment reductions from the major source category – “agriculture”, and smaller, equal percentage reductions from two other significant source categories - “channel erosion” and “forestry”. The TMDL to address the benthic impairment in Toms Brook is 4,866.0 t/yr of sediment and will require an overall reduction equal to 14.3% of the existing load. From the three alternative scenarios, Alternative 3 was recommended because it required no reductions from minor source categories, and required reasonable and achievable reductions from the other source categories.

CHAPTER 8: BENTHIC TMDL IMPLEMENTATION

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairment on Toms Brook. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf . With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

8.1. Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement. The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

8.2. Link to Ongoing Restoration Efforts

To address the historical winter upsets at the STP, the DEQ will recommend that the staff of the STP participate in the 104G Operations Training Grant Program to ensure that all available operational controls to prevent such upsets are utilized. In addition, the DEQ will continue to investigate the causes of the STP upsets, together with the STP and its consultant, and, if necessary, will require the STP to make changes recommended by the staff of the DEQ to reduce the incidence of upsets.

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. The BMPs required for the implementation of the sediment allocations in the watersheds contribute directly to the sediment reduction goals set as part of the Chesapeake Bay restoration effort. A new tributary strategy is currently being developed for the Shenandoah-Potomac River Basin to address the nutrient and sediment reductions required to restore the health of the Chesapeake Bay. Up-to-date information on tributary strategy development can be found at http://www.snr.state.va.us/Initiatives/TributaryStrategies/shenandoah.cfm .

8.3. Reasonable Assurance for Implementation

8.3.1. Follow-Up Monitoring

VADEQ will continue sampling at the established biological monitoring station on Toms Brook (TMB000.78) in accordance with its biological monitoring program. DEQ has also established 2 additional benthic monitoring stations on Toms Brook to provide additional information on the level of impairment in different segments of the stream. One of these new stations is located above the STP and the other is between the STP and the confluence with Jordon Run, and complement the existing station which is located below the confluence with Jordon Run. Information on the benthic community in each of the segments between stations may be used in the implementation planning phase to better focus implementation efforts. VADEQ will use data from these monitoring stations and related ambient monitoring stations to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

8.3.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 “Guidance for Water Quality-Based Decisions: The TMDL Process.” The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act’s Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

8.3.3. Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia’s Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture’s Conservation Reserve Enhancement Program (CREP) and the Environmental Quality Incentive Program (EQIP), the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

CHAPTER 9: PUBLIC PARTICIPATION

Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progess made. In May 2002, an initial trip was made to the watershed to meet with regional DEQ and local NRCS field personnel, to take a windshield tour of the watershed led by Jim Lawrence with The Opequon Watershed group, and to introduce ourselves to the coordinator of the Friends of the Shenandoah River volunteer monitoring group. On March 27, 2003, the first public meeting on the Toms Brook TMDL was held at the Toms Brook Fire Station in Toms Brook, Virginia, with approximately 24 people in attendance. The purpose of this meeting was threefold: to inform local citizens and stakeholders of the impairment, to explain the work that had been completed up to that point in identifying the benthic stressors, and to encourage the sharing of information about the watershed. Personnel from the Department of Environmental Quality (DEQ), the Department of Conservation and Recreation (DCR), and the Virginia Tech TMDL group presented information and data. Questions from the audience followed the presentations. The second and final public meeting was held on January 13, 2004, at the Toms Brook Fire Station in Toms Brook. Approximately 30 people attended the final meeting. Copies of the presentation materials were available for public distribution at the meeting. The draft TMDL report was made available to the public for comment at the final public meeting and on the DEQ website. Four sets of comments were received, and DEQ responded to each of those comments in the final draft.

CHAPTER 10: REFERENCES

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APPENDIX A.Glossary of Terms

Allocation
That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario
A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Ambient Water Quality
Level of water quality constituents collected as part of a routine monitoring program.

Ammonia (NH_3)
An inorganic nitrogen compound.

Aquatic Ecosystem
The living and nonliving components of a water body, i.e. its physical, chemical, and biological components.

Background levels
Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

Benthic Macroinvertebrates
Organisms living in or on the bottom of a waterbody that are visible without a microscope ("macro-") and lack backbones ("invertebrates"). Benthic macroinvertebrates include larval or nymph forms for insects (e.g. stoneflies, mayflies, etc.), crustaceans (e.g. crayfish), snails, mussels, clams, worms, and leeches.

Best Management Practices (BMP)
Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Bioassessment
The process of evaluating the algal, benthic macroinvertebrate, and/or fish communities to determine whether a water body suppors the state-defined designated use for aquatic life.

Biochemical Oxygen Demand (BOD)
Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity
A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted, habitat.

Calibration
The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Conductivity
An indirect measure of the presence of dissolved substances within water.

Direct nonpoint sources
Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: direct deposits of fecal material to streams from livestock and wildlife.

Dissolved Oxygen (DO)
The amount of oxygen dissolved in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Ecoregion
A region defined in part by its chared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Erosion
The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint source pollution in the United States.

Eutrophication

The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Hydrology

The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Load allocation (LA)

The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)

A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Metrics

Indices or parameters used to measure some aspect or characteristic of a water body's biologcal integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

Model

Mathematical representation of hydrologic and water quality processes. Effects of Land use, slope, soil characteristics, and management practices are included.

Monitoring

Periodic or continuous sampling and measurement to determine the physical, chemical, and biological status of a particular media like air, soil, or water.

Nitrate (NO_3^-)

An inorganic nitrogen compound. Nitrate may be naturally present in water, but high concentrations are most likely due to fertilizer runoff, livestock facilities, sanitary wastewater discharges, and/or atmospheric deposition (dissolved in precipitation).

Nitrogen

An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source
Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Nutrient
An element or compound essential to life, including carbon, oxygen, nitrogen, phoshphorus, and many others; as a pollutant, any element or compound, such as phosphorus or nitrigen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic Matter
Plant and animal residues, or substances made by living organisms.

Orthophosphate (PO_4^{-3})
Often referred to simply as phosphate. Most phosphorus exists in water in this form. Plants use orthophosphate as a phosphorus source. Like nitrates, phosphate in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

pH
A numerical measure of acidity or alkalinity. The pH scale ranges from 1 (acidic) to 14 (alkaline). A pH of 7 is neutral.

Phosphorus
An essential nutrient to the growth of organisms. In excessive amounts, phosphorous contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Point source
Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution
Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Public Comment Period
The time allowed for the public to express its views and concerns regarding action proposed by a state or federal agency.

Rapid Bioassessment Protocol (RBP)
A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualititative assessment of their habitat. RBP scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach
Segment of a stream or river.

Reference Conditions
The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Reference Site
A benchmark against which that water quality in a specific watershed is compared; for example, a biological evaluation in the watershed would be compared with that from a reference site (unimpaired) to determine the level of impairment.

Riparian
Pertaining to the banks of a river, stream, pond, lake, etc., as well as to the plant and animal communities along such bodies of water.

Runoff
That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Sediment
In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquatic systems as a result of erosion.

Simulation
The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Staged Implementation
A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder
In this context, any person or organization with a vested interest in TMDL development and implementation in a specific watershed.

Stressor
Any substance or condition that adversely impacts the aquatic ecosystem.

Suspended Solids
Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Total Dissolved Solids (TDS)
A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL)
The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

TMDL Implementation Plan
A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously imparied water meeting water quality standards and achieving a "fully supporting" use support status.

Urban Runoff
Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)
Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload allocation (WLA)

The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard
Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed
A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Many of the glossary terms are taken from:

Benham, Brian, Kevin Brannan, Theo Dillaha, Saied Mostaghimi, and Gene Yagow. 2002. TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Virginia Cooperative Extension. Publication Number 442-758. Virginia Tech. Blacksburg, Virginia.

APPENDIX B. Subwatershed Model Inputs and Sediment Loads

Table B.1. Watershed and Subwatershed Land Use Distributions

MINOR1	ANCODE	Watershed Name	hit	lot	hay	pas	pcg	ppl	man	for	dsf	pur	imp	water	Land_Total
502	HYS	Hays Creek	60.3	260.1	2,465.3	5,949.5	1,306.7	0.0	0.6	10,708.8	8.1	18.0	12.0	11.5	**20,789.4**
508	TMB	Toms Brook	59.8	35.8	655.5	878.4	339.5	129.6	0.3	1,891.5	5.6	150.2	100.2	6.4	**4,246.4**
5021	HYSadj	Hays Creek Area-adjusted	12.3	53.1	503.5	1,215.2	266.9	0.0	0.1	2,187.4	1.7	3.7	2.4	2.4	**4,246.4**
5081	TMB1	Toms Brook - Outlet	0.1	0.0	3.2	4.3	1.7	0.6	0.0	29.8	0.0	0.1	0.0	0.0	**39.9**
5082	TMB2	Jordon Run	19.4	11.6	292.2	391.5	151.3	57.8	0.1	399.9	0.2	81.1	54.0	1.4	**1,459.1**
5083	TMB3	Toms Brook Branch	40.3	24.1	360.1	482.6	186.5	71.2	0.1	1,461.8	5.4	69.1	46.1	5.0	**2,747.4**

Table B.2. Average Slope (%) by Land Use and Subwatershed

MINOR1	ANCODE	Watershed Name	hit/lot	hay/pas/man	forest	disturbed for	pur	imp
502	HYS	Hays Creek	10.69	12.59	20.07	16.40	9.72	9.86
508	TMB	Toms Brook	7.01	7.61	15.85	19.25	7.32	7.79
5021	HYSadj	Hays Creek Area-adjusted	10.69	12.59	20.07	16.40	9.72	9.86
5081	TMB1	Toms Brook - Outlet	17.91	12.72	17.14	0.00	21.30	21.30
5082	TMB2	Jordon Run	5.21	6.26	9.80	3.76	5.93	5.68
5083	TMB3	Toms Brook branch	6.14	7.87	18.07	20.63	6.76	6.15

Table B.3. Average Soil Erodibility (K-factor) by Land Use and Subwatershed

MINOR1	ANCODE	Watershed Name	hit/lot	hay/pas/man	forest	disturbed for	pur	imp
502	HYS	Hays Creek	0.286	0.280	0.272	0.270	0.259	0.000
508	TMB	Toms Brook	0.314	0.316	0.245	0.173	0.321	0.000
5021	HYSadj	Hays Creek Area-adjusted	0.286	0.280	0.272	0.270	0.259	0.000
5081	TMB1	Toms Brook - Outlet	0.320	0.286	0.256	0.000	0.320	0.000
5082	TMB2	Jordon Run	0.321	0.321	0.303	0.320	0.332	0.000
5083	TMB3	Toms Brook branch	0.325	0.319	0.228	0.170	0.305	0.000

Table B.4. Hydrologic Soil Group (HSG) Distribution by Subwatershed

	A	B	C	D	E	F	G	H
16	MINOR1	ANCODE	Watershed Name	LAND_SQKM	% HSG A	% HSG B	% HSG C	% HSG D
17	502	HYS	Hays Creek	207.894	3	35	47	16
18	508	TMB	Toms Brook	42.464	0	13	82	5
19	5021	HYSadj	Hays Creek - area-adjusted to Toms Brook	42.464	3	35	47	16
20	5081	TMB1	Outlet	0.399	0	11	89	0
21	5082	TMB2	Jordon Run	14.591	0	2	94	3
22	5083	TMB3	Toms Brook	27.474	0	19	75	6

Table B.5. Channel Erosion Parameters

	Units	% developed land (%)	No. of beef and dairy (AU)	animal density (AU/ac.)	area-weighted CN	area-weighted KF	aFactor	stream length (meters)	Mean channel depth (m)
502	HYS	0.06	2471	0.0481	71.92	0.276	0.0000001	151,387.3	1.513
508	TMB	2.36	540	0.0515	75.64	0.277	0.0000212	18,892.2	0.974
5021	HYSadj	0.06	505	0.0481	71.92	0.276	0.0000001	30,922.0	0.974
5081	TMB1	0.09	40	0.4060	73.13	0.264	0.0000031	986.4	0.974
5082	TMB2	3.70	200	0.0555	77.17	0.305	0.0000496	7,421.1	0.724
5083	TMB3	1.68	300	0.0442	74.37	0.265	0.0000051	10,484.7	0.863

Table B.6. Other GWLF Land use-Specific Parameters

		Runoff Curve Numbers (CN)					ET Cover Coefficient		Sediment Buildup Rate
Land Use	Description	HSG = A	HSG = B	HSG = C	HSG = D	C-Factor	(dormant)	(growing)	(kg/ha-day)
LOW_TILL	N. Mtn&Valley (Region 1)	67.3	77.3	84.5	87.7	0.155	0.55	1.00	
HIGH_TILL	N. Mtn&Valley (Region 1)	69.2	79.2	86.4	89.8	0.352	0.40	1.00	
HAY	close-seeded…,contour, good	55	69	78	83	0.013	0.90	1.00	
PASTURE	pasture or range, fair	49	69	79	84	0.013	0.90	0.90	
PASTURE-CATTLE GR	pasture or range, fair	49	69	79	84	0.013	0.90	1.00	
PASTURE-POULTRY L	pasture or range, fair	49	69	79	84	0.013	0.90	1.00	
MANURE_ACRES	Impervious, paved, open ditches	98	98	98	98	0.000	0.30	0.30	
FOREST	woods, fair	36	60	73	79	0.0005	0.51	1.00	
DISTURBED FOREST	fallow, bare soil	77	86	91	94	0.175	0.30	0.30	
PERV_URBAN	open space, 50-75% cover	49	69	79	84	0.003	1.00	1.00	1.30
IMPERV_URBAN		98	98	98	98		0.00	0.00	2.50

Table B.7. Sediment Loads by Subwatershed – Toms Brook and Area-adjusted Hays Creek

	SDR Ratio				
	1.000	0.826	0.904	SDRcorrected	
Land Use	**TMB1**	**TMB2**	**TMB3**	**TMB Total**	**HYSadj**
Hi-Till Cropland	354.07	458.99	1,161.11	1,974.17	325.09
Lo-Till Cropland	85.47	108.49	272.39	466.35	1,015.03
Hay	55.41	227.90	356.60	639.91	831.24
Pasture	53.84	319.16	499.59	872.59	2,043.18
Pasture-cattle graze	22.12	131.14	205.27	358.53	450.66
Pasture-poultry litter	8.45	50.04	78.33	136.82	0.00
Manure Acres	0.00	0.00	0.00	0.00	0.00
Forest	6.26	17.44	95.48	119.17	122.40
Disturbed Forest	-4.54	1.37	200.92	197.75	74.53
Pervious Urban	5.84	15.69	13.86	35.39	0.94
Impervious Urban	7.50	16.37	16.93	40.80	1.00
Channel erosion	145.07	90.55	23.85	259.47	0.00
Point Source	0.00	0.00	2.43	2.43	0.00
Sub-Totals					
Agriculture	579.35	1,295.72	2,573.29	4,448.36	0.00
Forestry	1.72	18.80	296.40	316.92	0.00
Urban	13.34	32.06	33.22	78.62	0.00
Total Sediment	**739.48**	**1,437.13**	**2,926.76**	**5,103.37**	**4,866.03**